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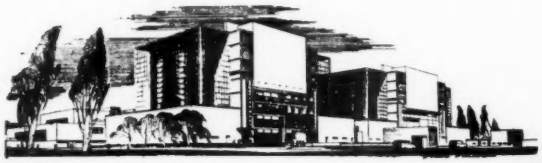

Eight Companies make

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THE NUCLEAR POWER PLANT COMPANY LIMITED

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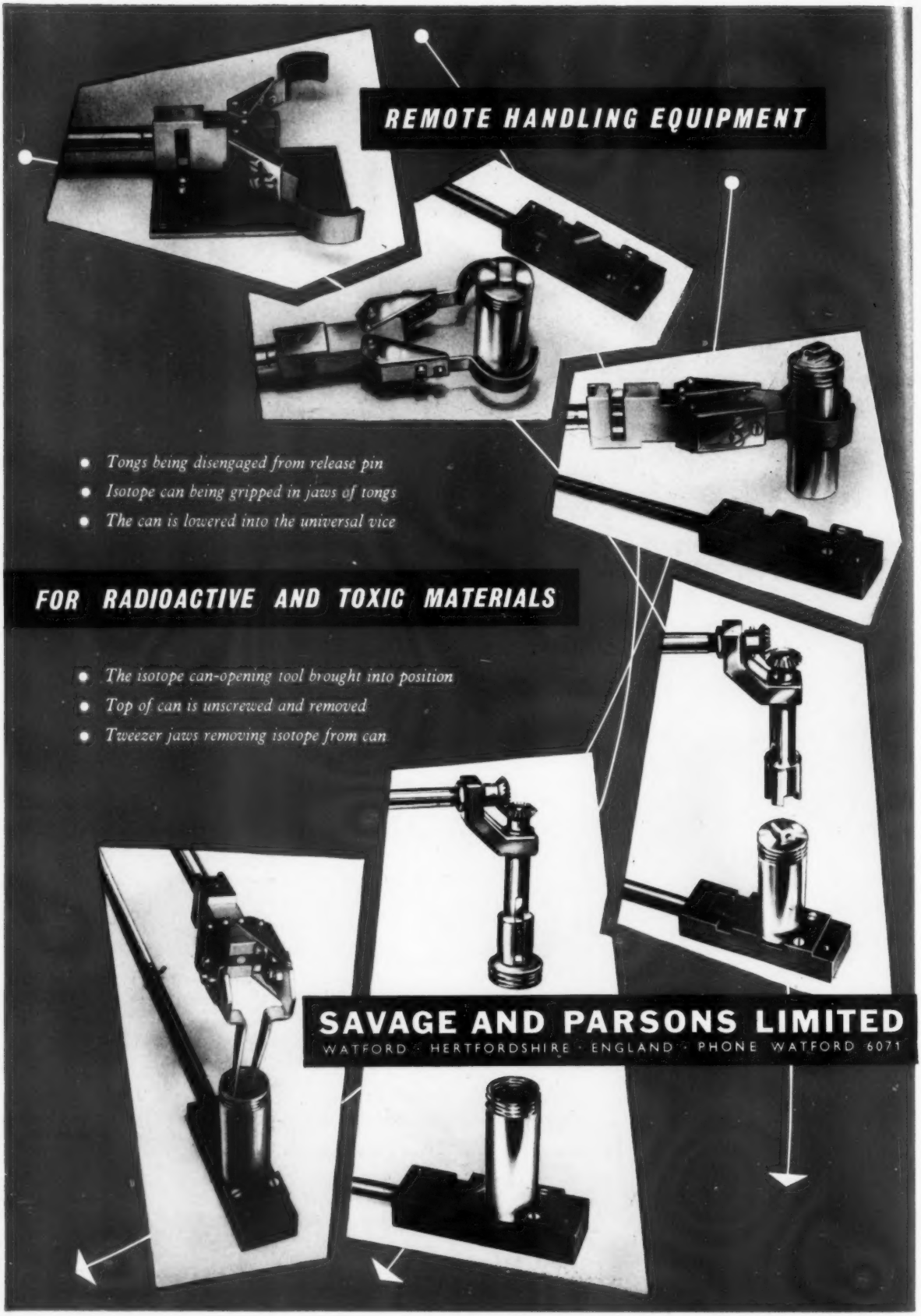
REMOTE HANDLING EQUIPMENT
• Tongs being disengaged from release pin
• Isotope can being gripped in jaws of tongs
• The can is lowered into the universal vice
FOR RADIOACTIVE AND TOXIC MATERIALS
• The isotope can-opening tool brought into position
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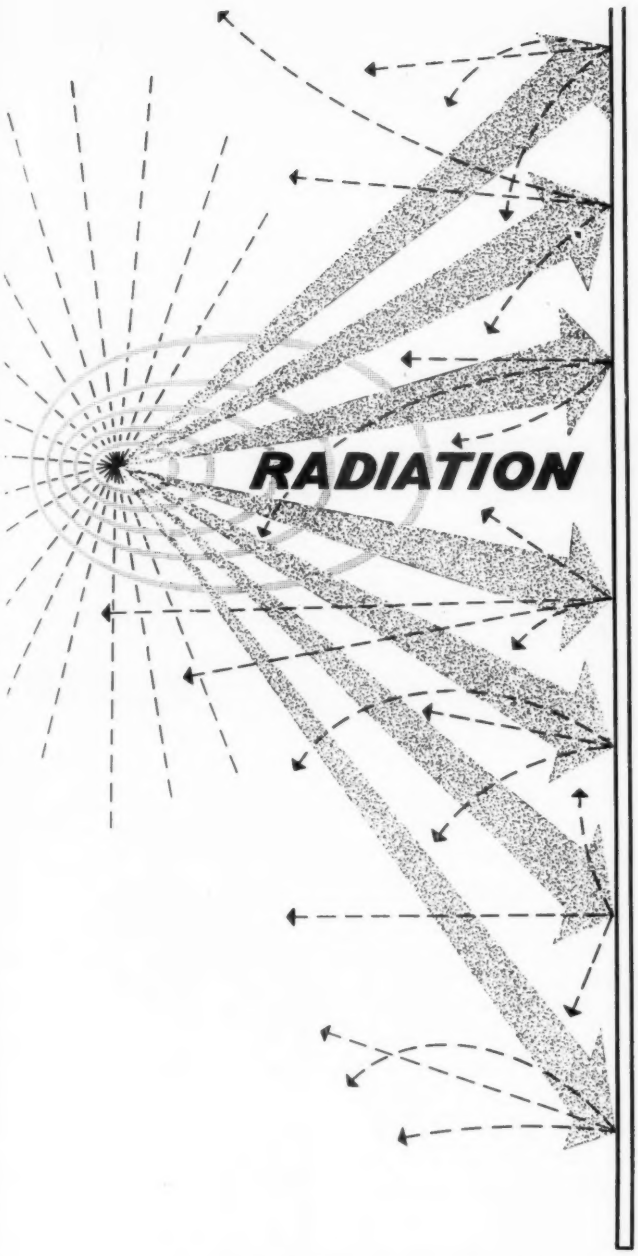

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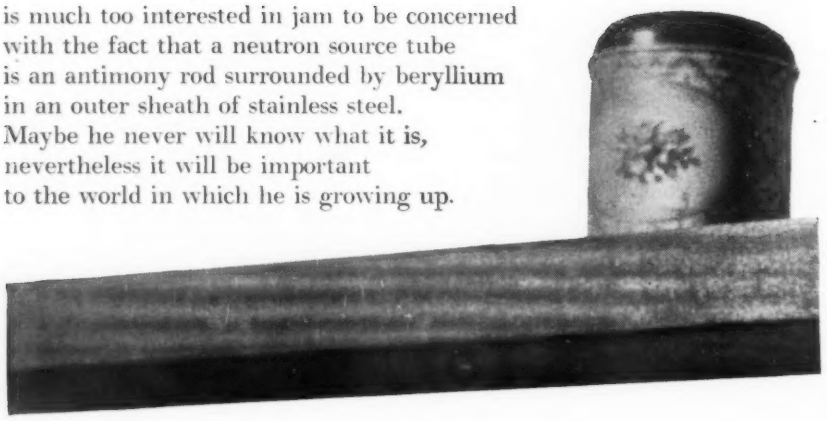
Johnny

is much too interested in jam to be concerned
with the fact that a neutron source tube
is an antimony rod surrounded by beryllium
in an outer sheath of stainless steel.
Maybe he never will know what it is,
nevertheless it will be important
to the world in which he is growing up.



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at the Bradwell Nuclear Power Station.
And the first commercial production of these
components has been undertaken by Talbot Stead
on behalf of the Nuclear Power Plant Co. Ltd.
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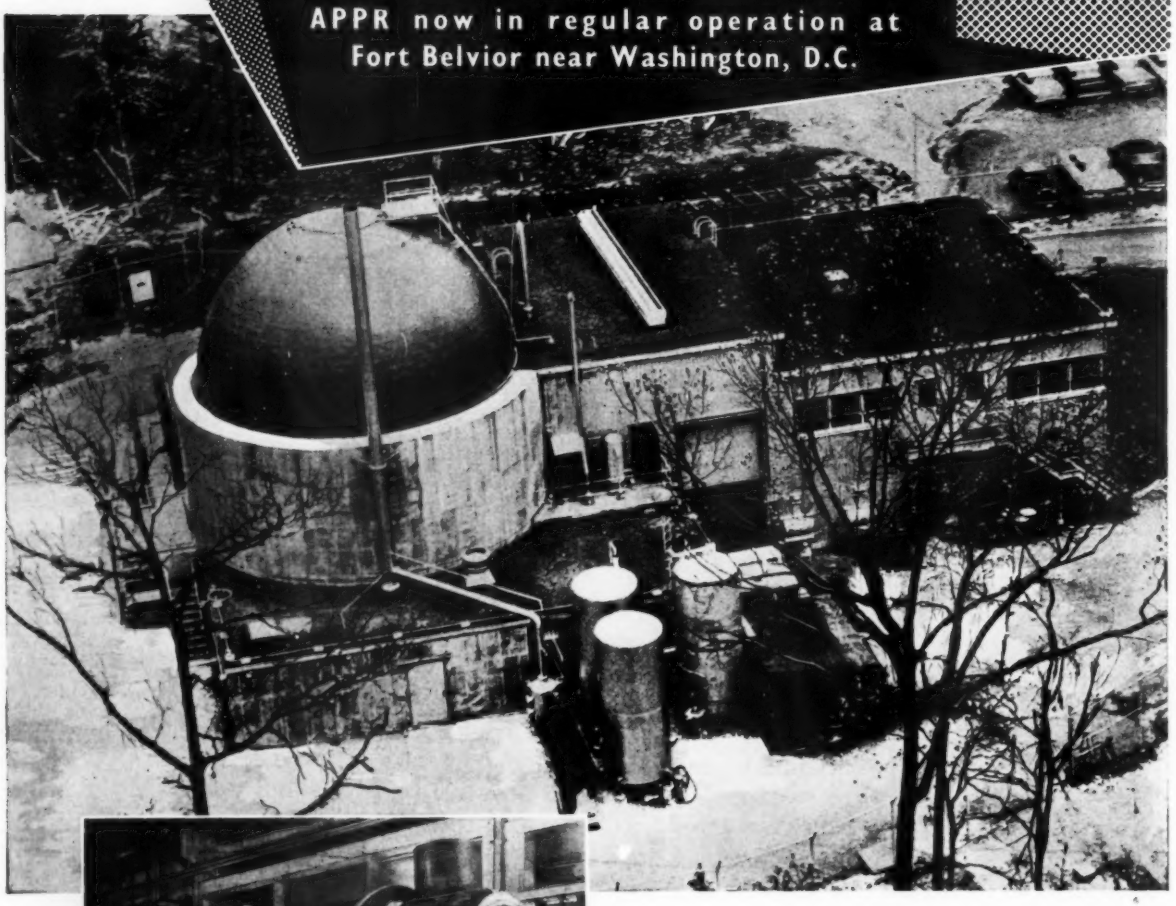

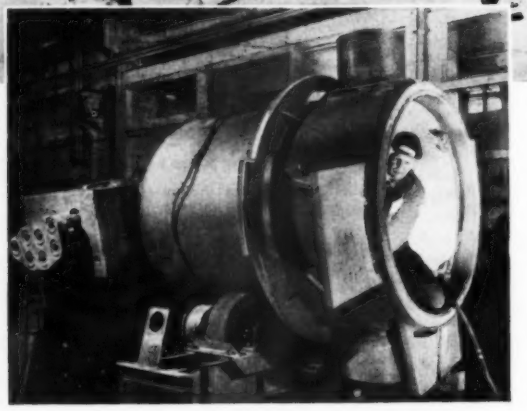

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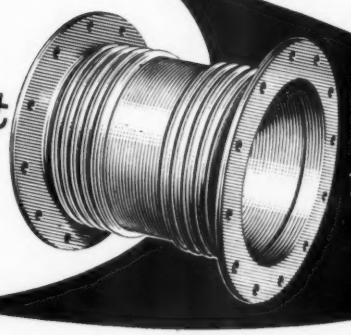
Let's get  together with . . .

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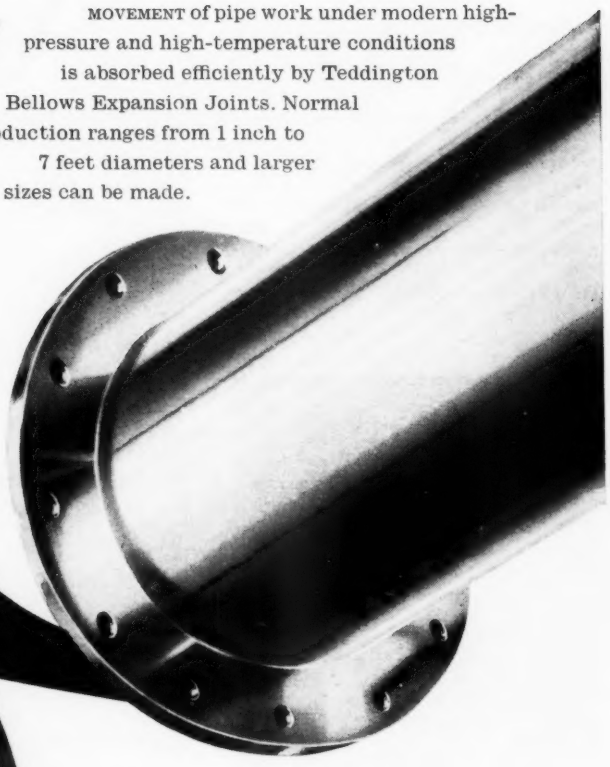

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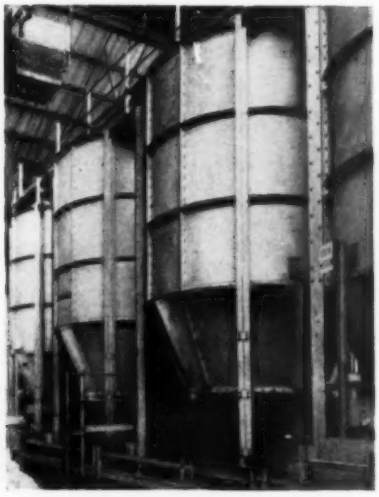

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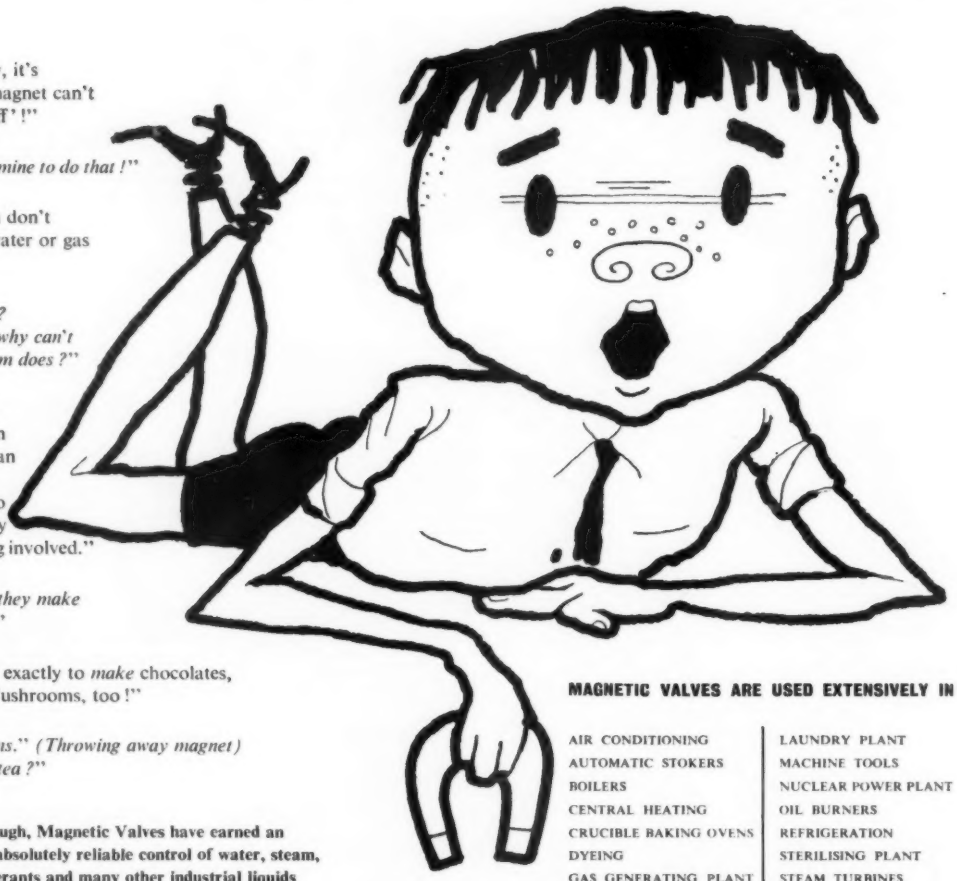

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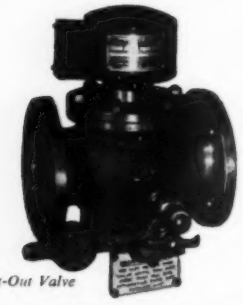

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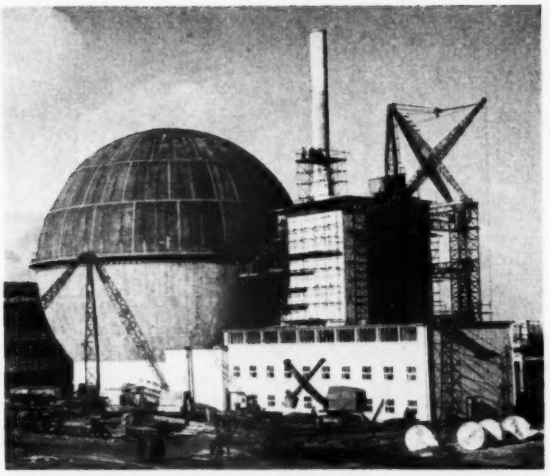
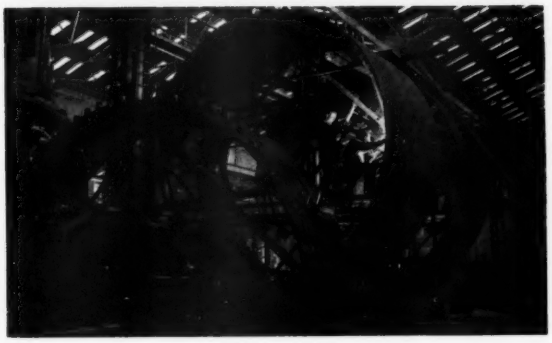
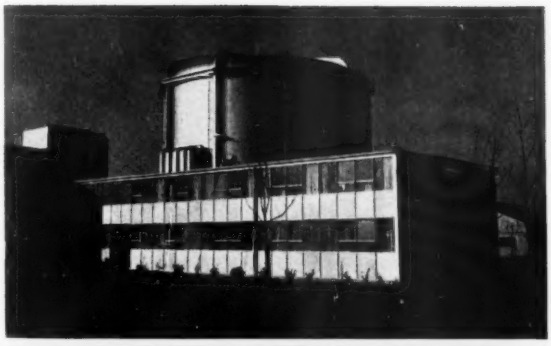
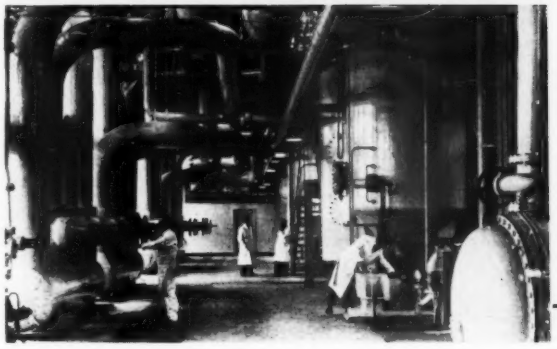




why Kodak INDUSTRIAL X-RAY FILMS





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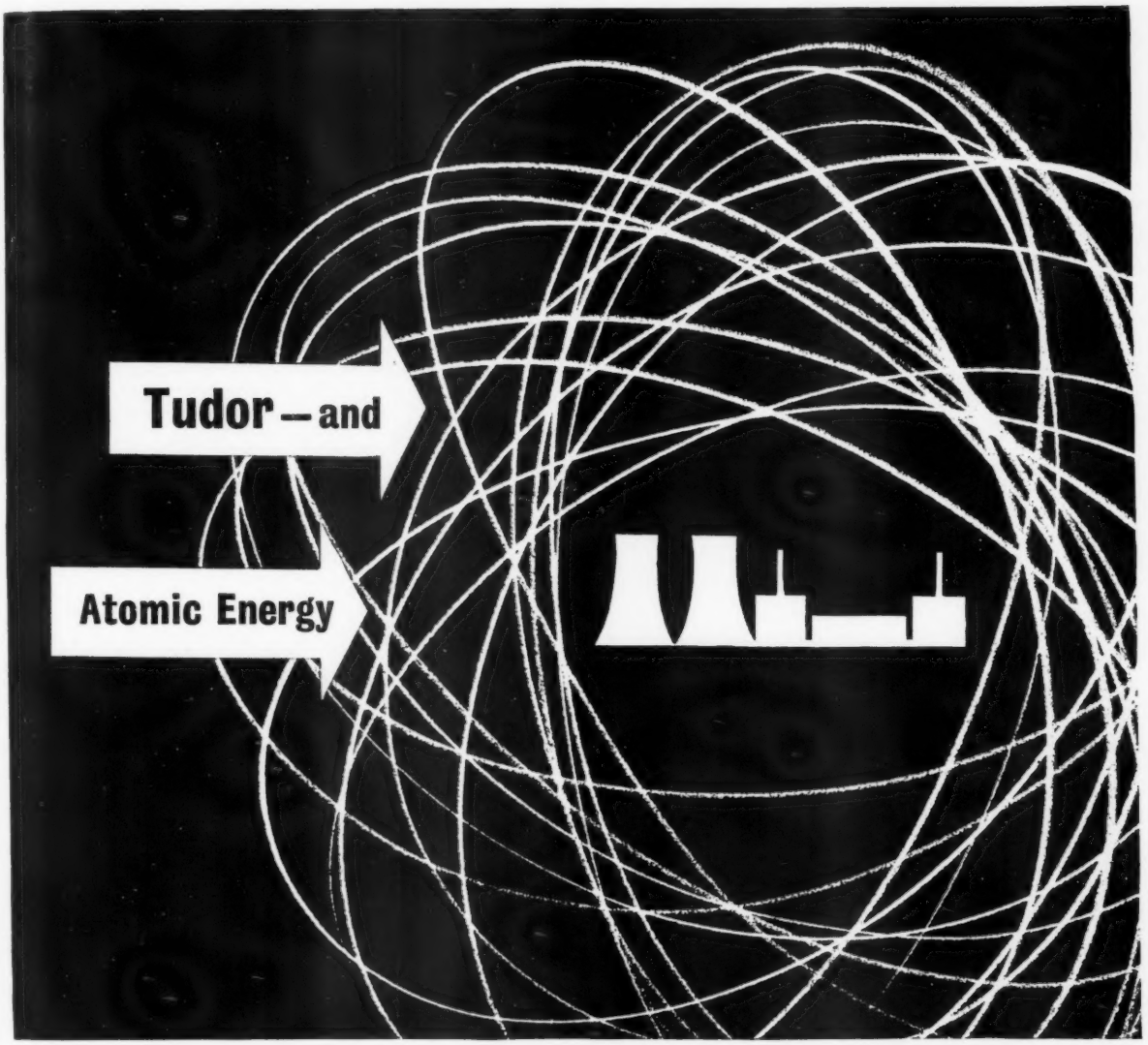

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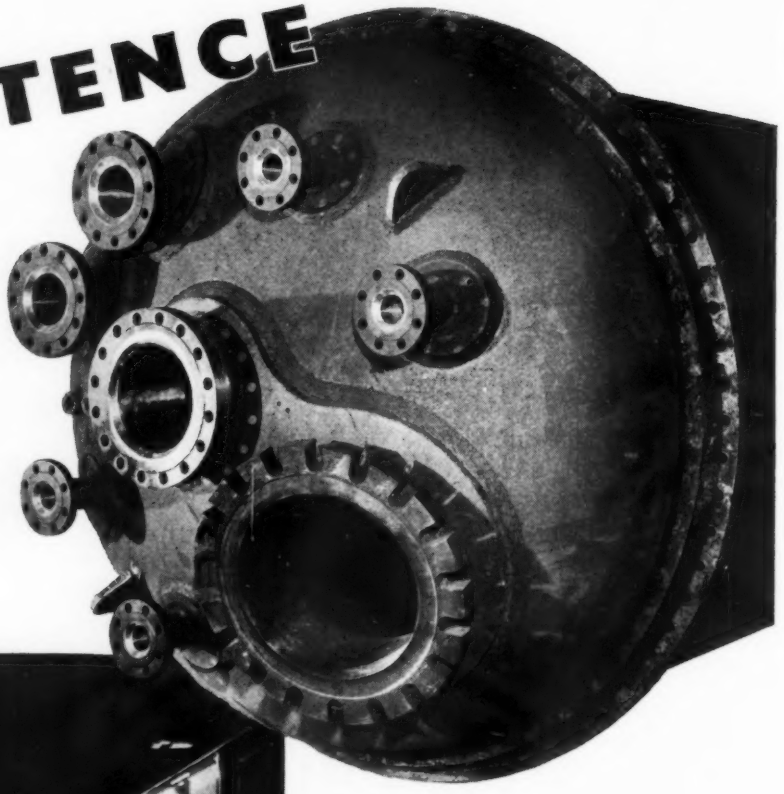

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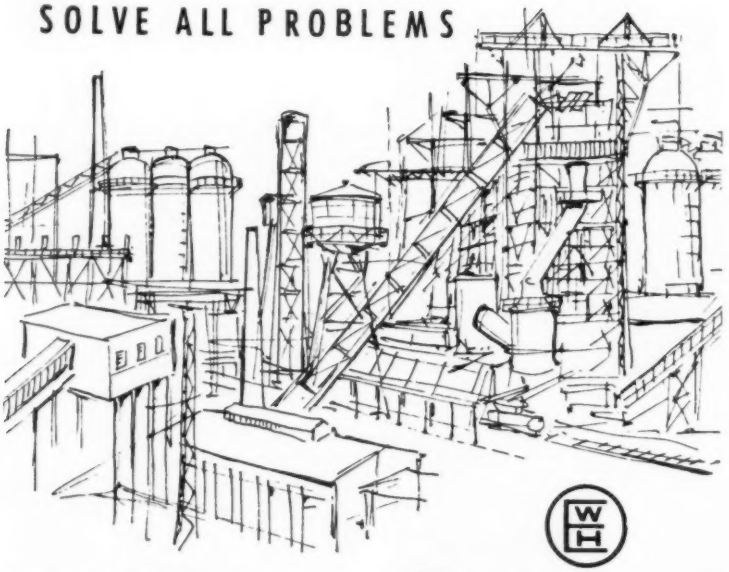

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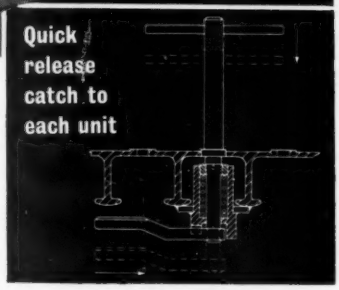

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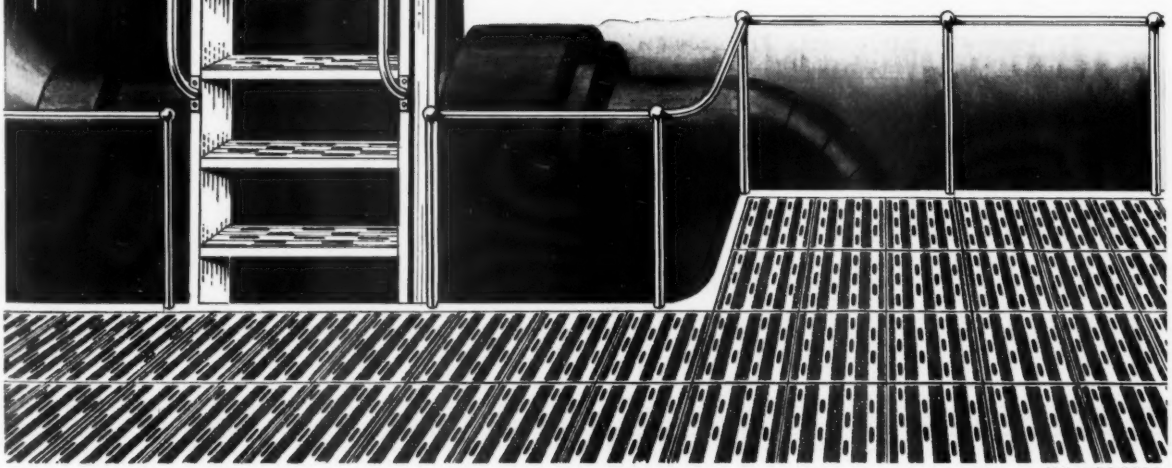

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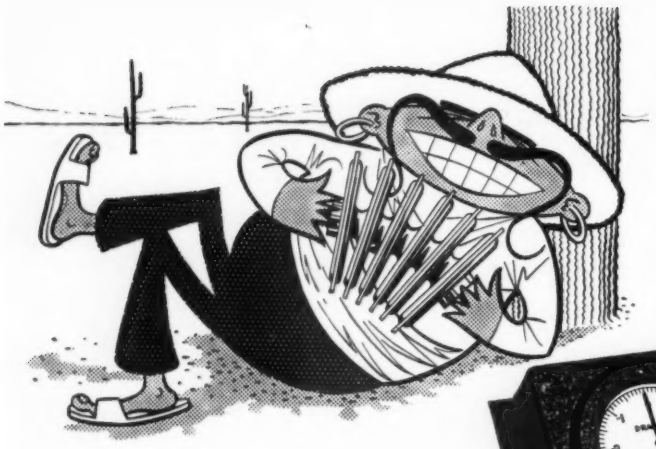

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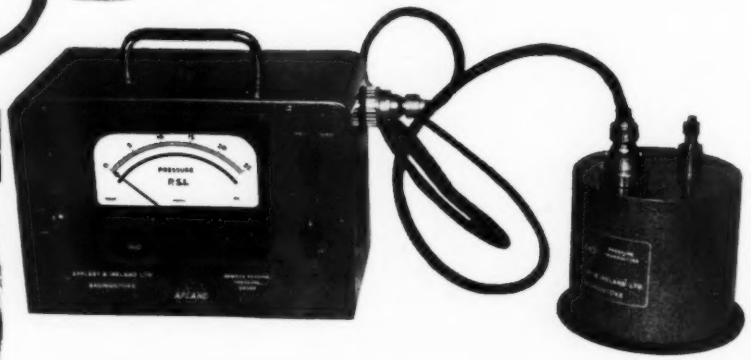

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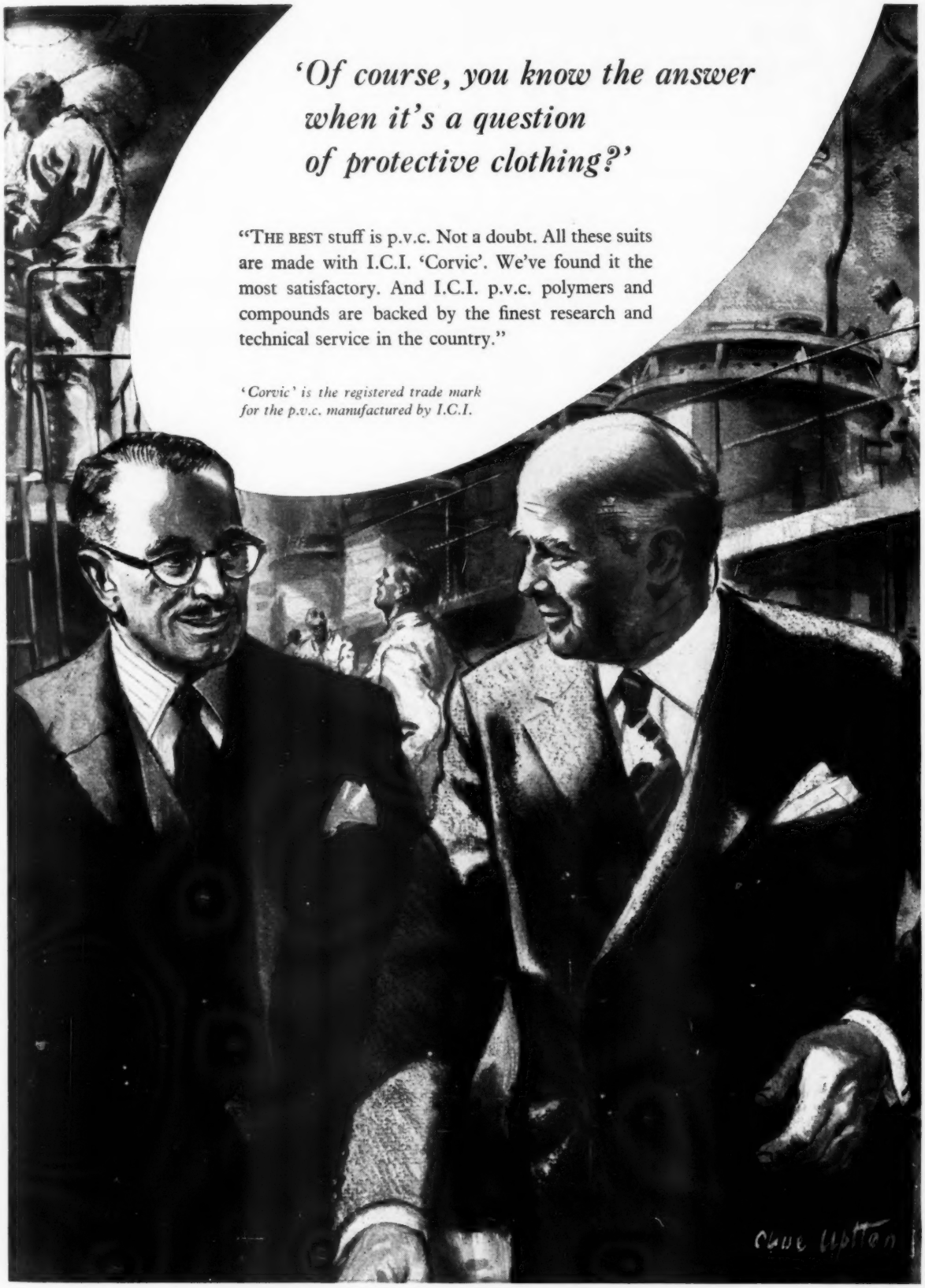

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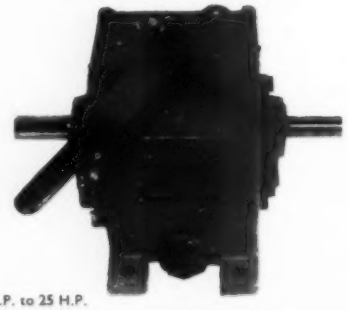

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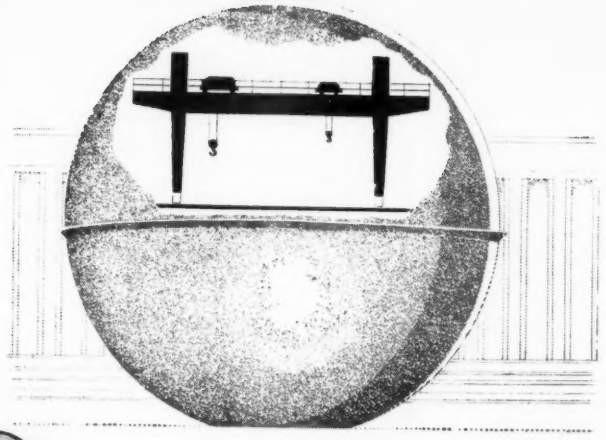

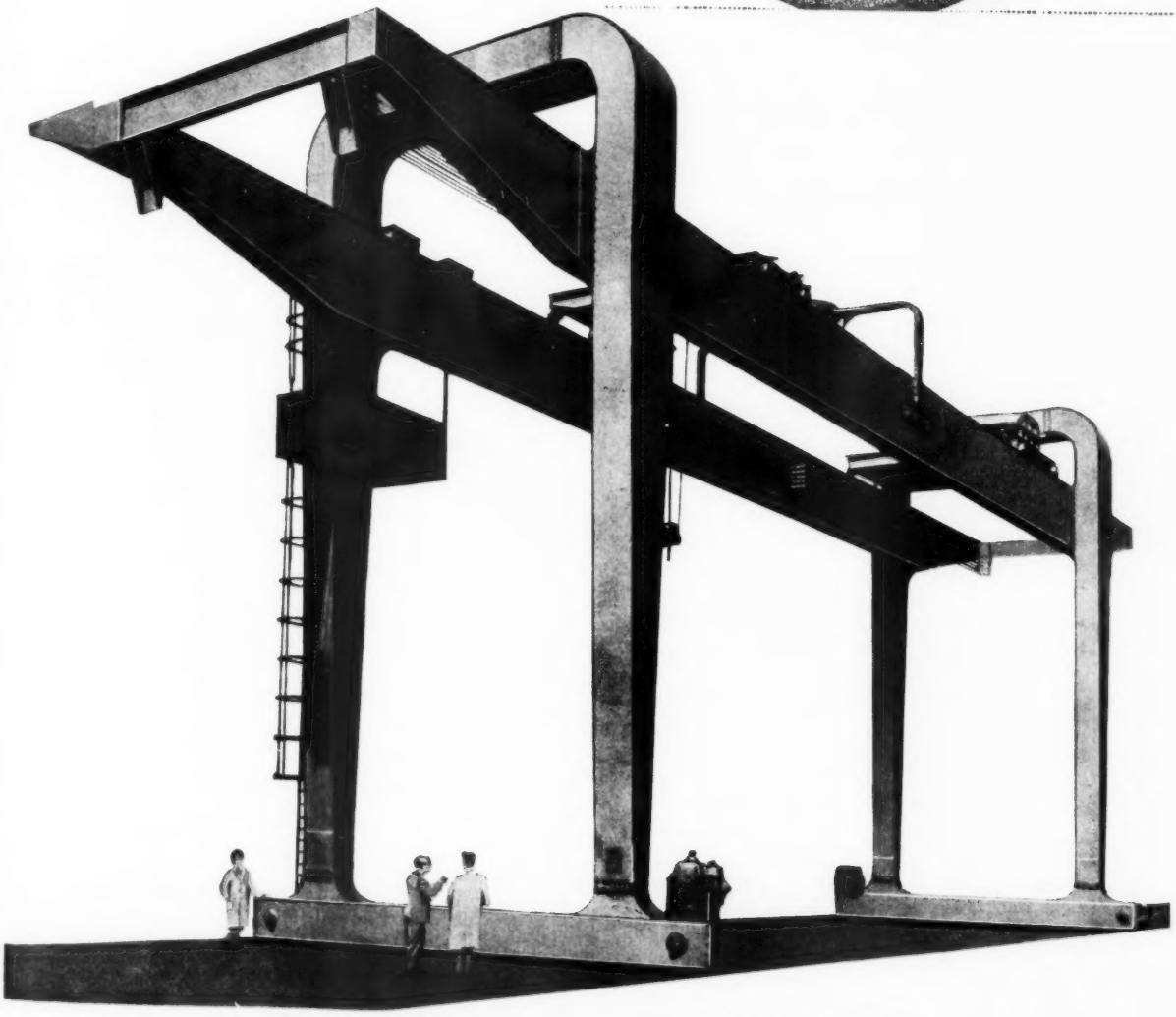

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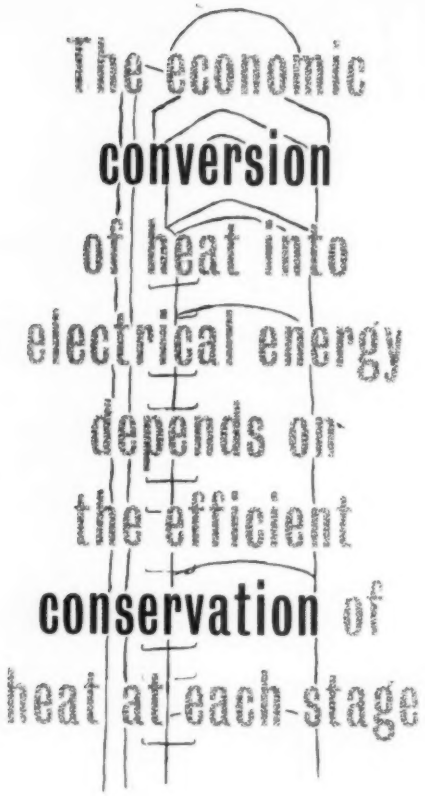

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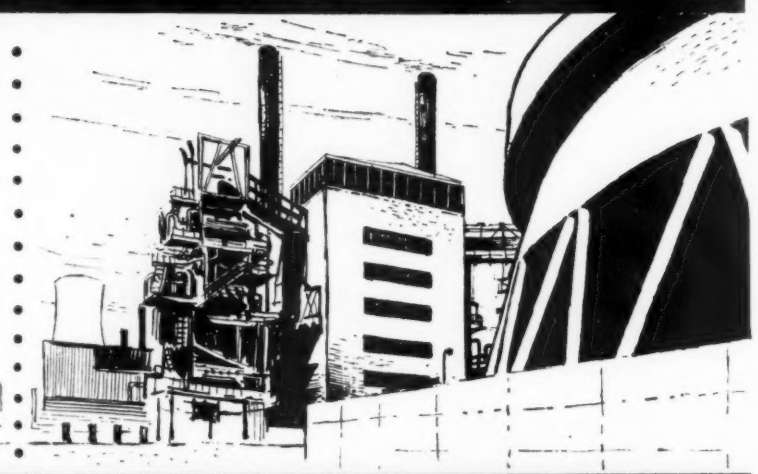

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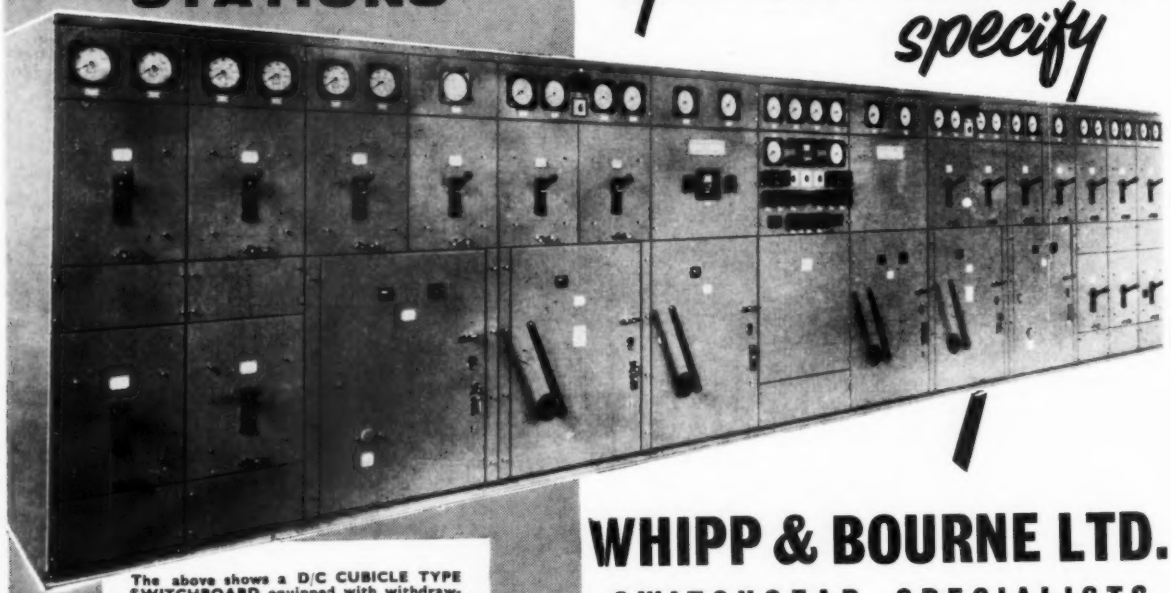

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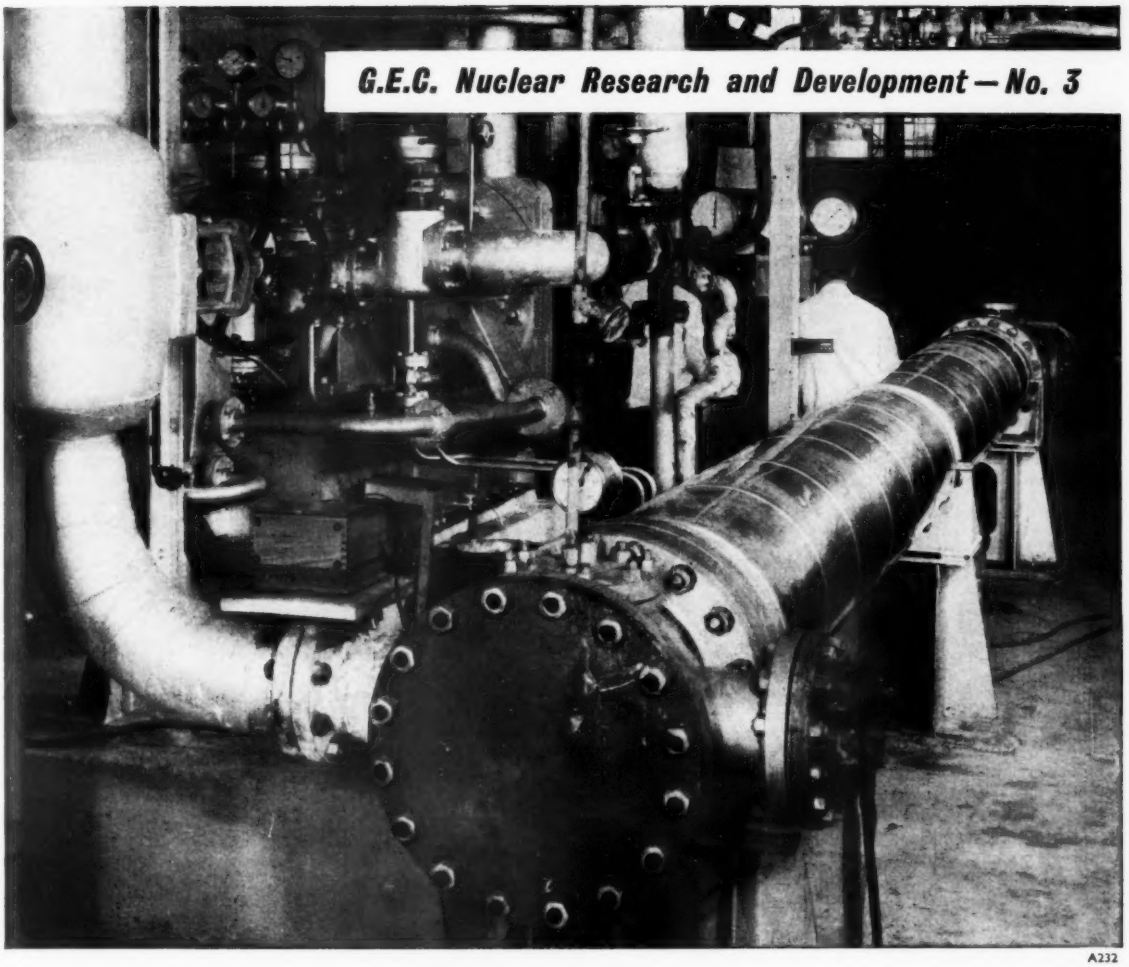

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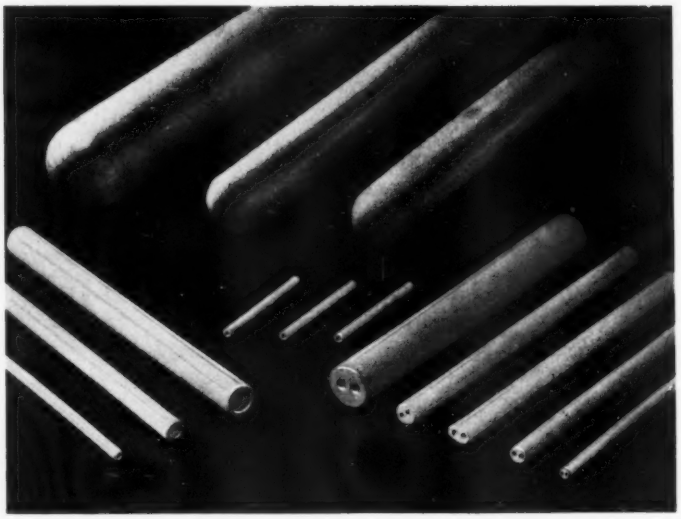

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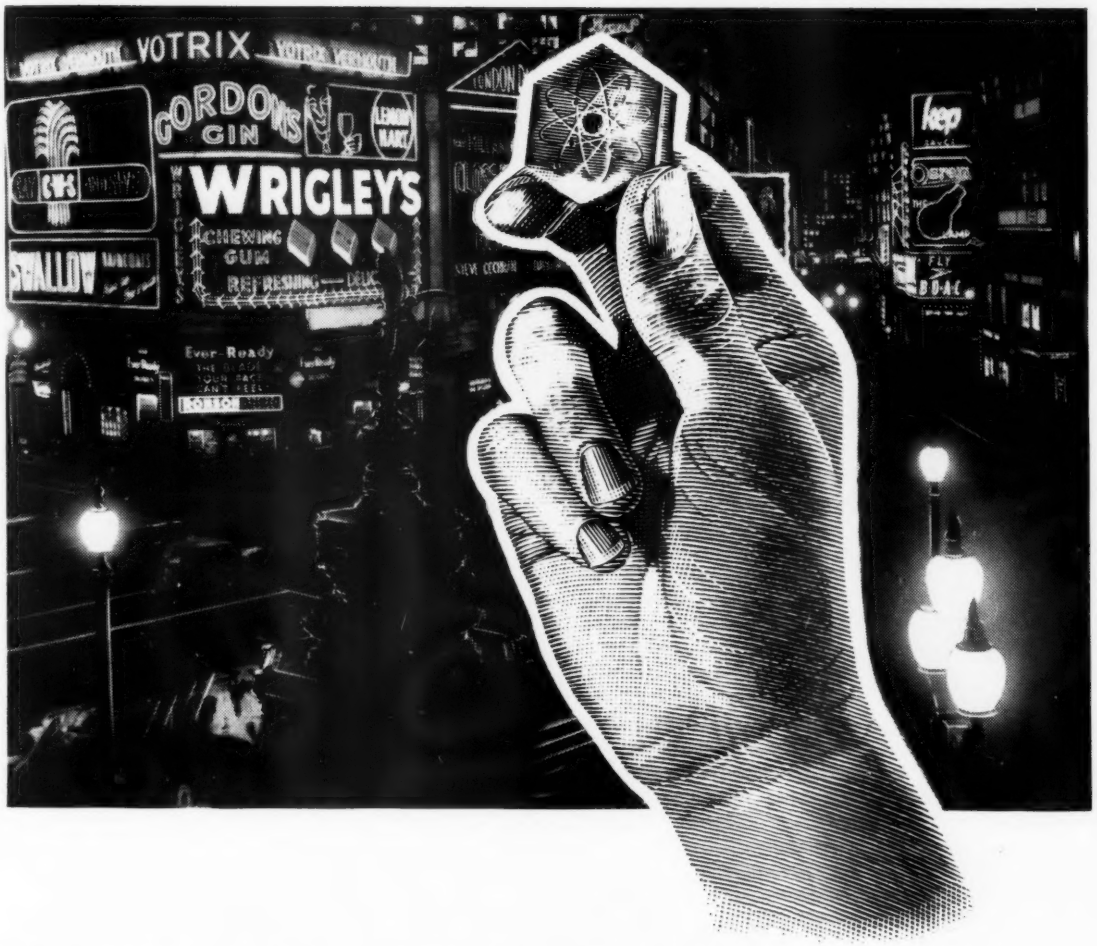

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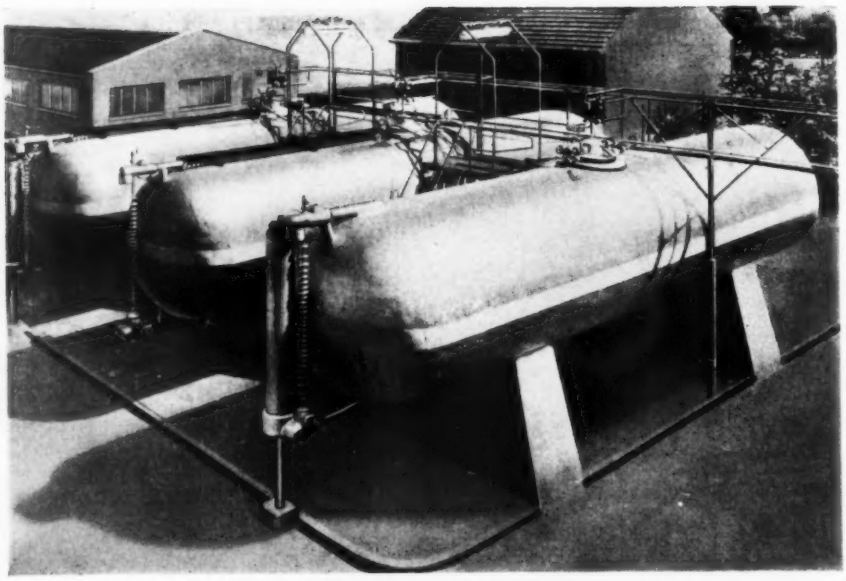

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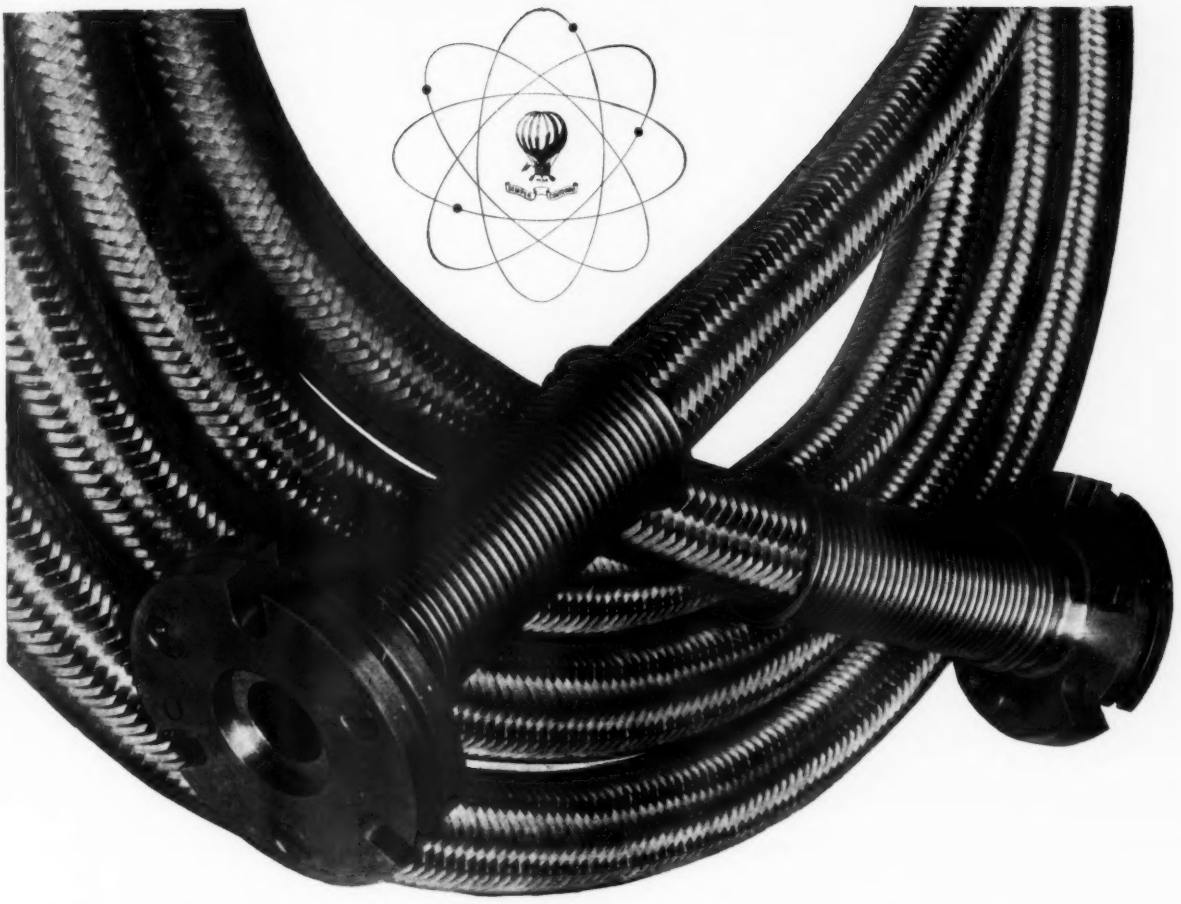

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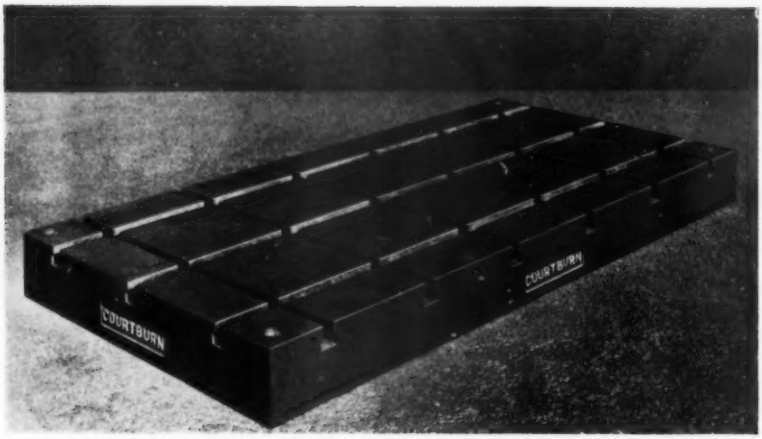

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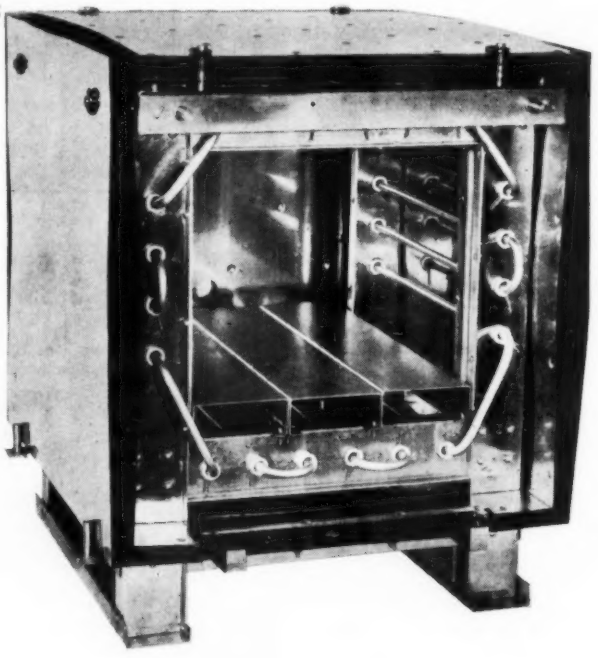

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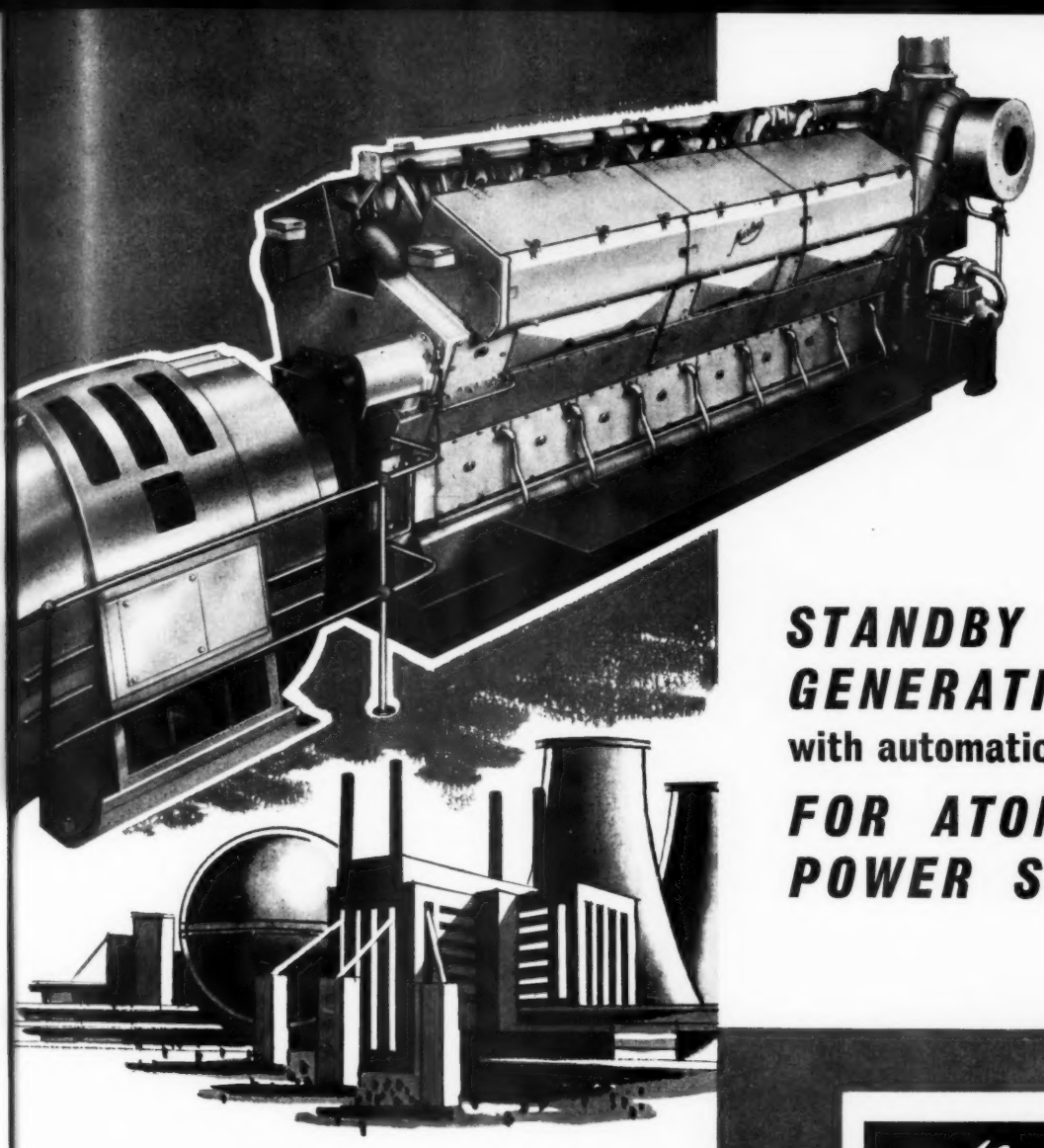

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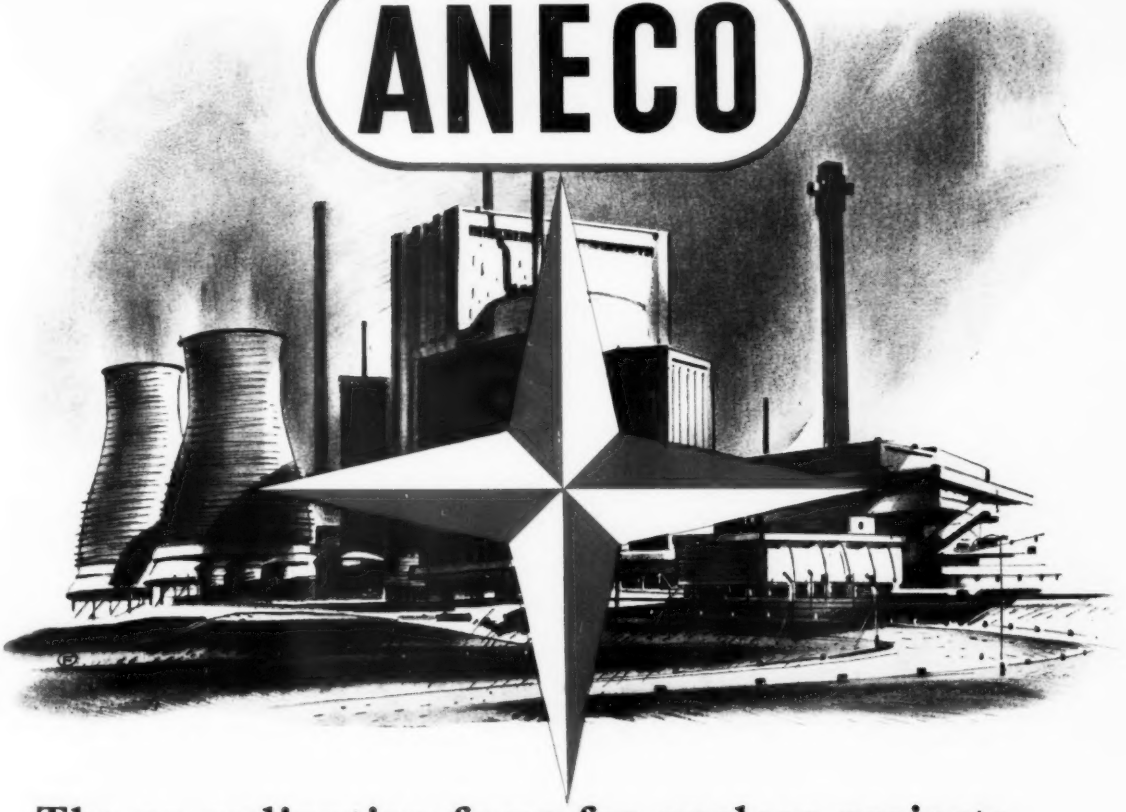

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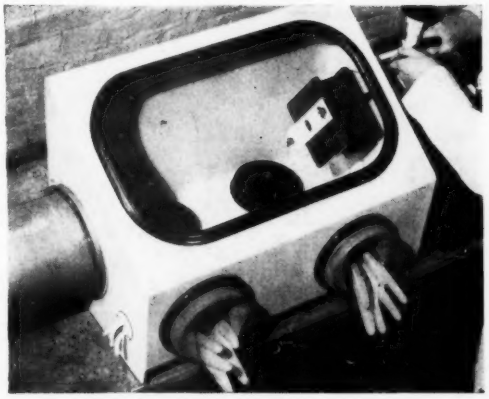

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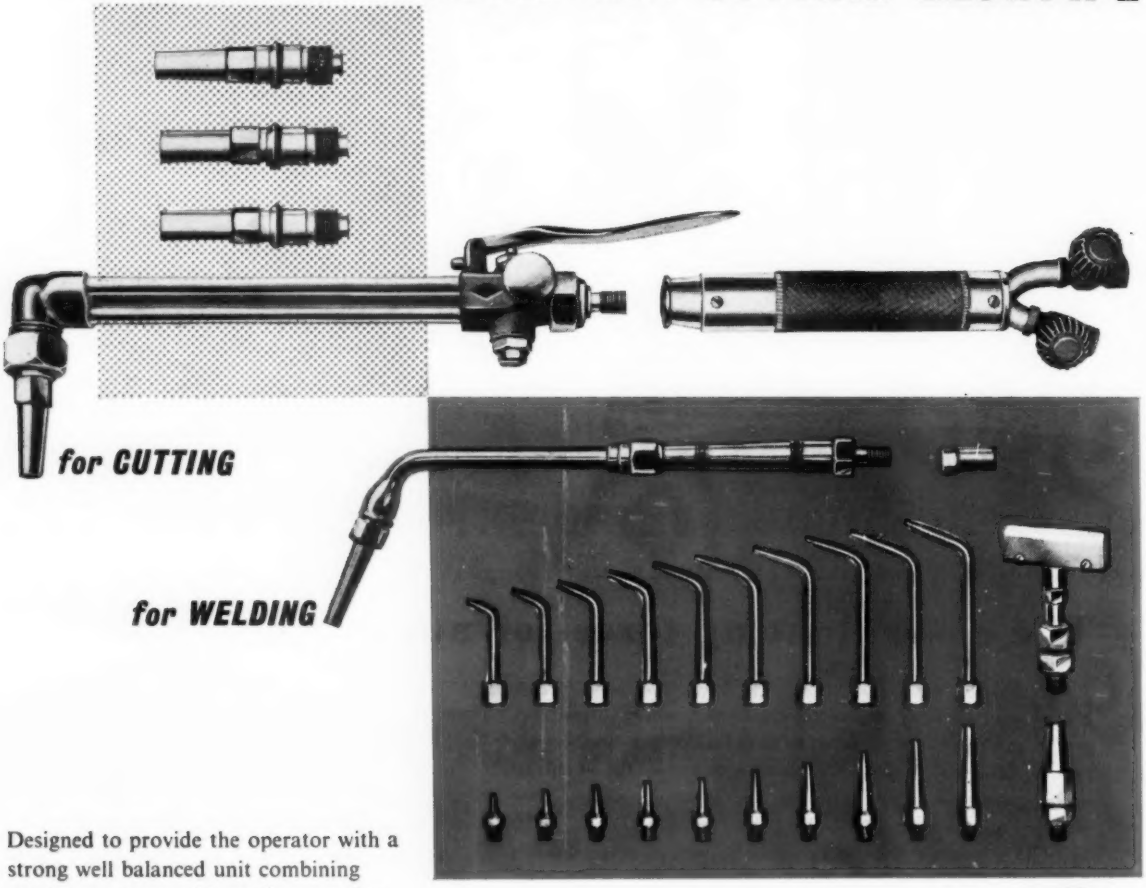

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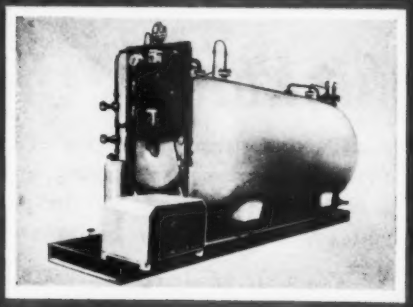

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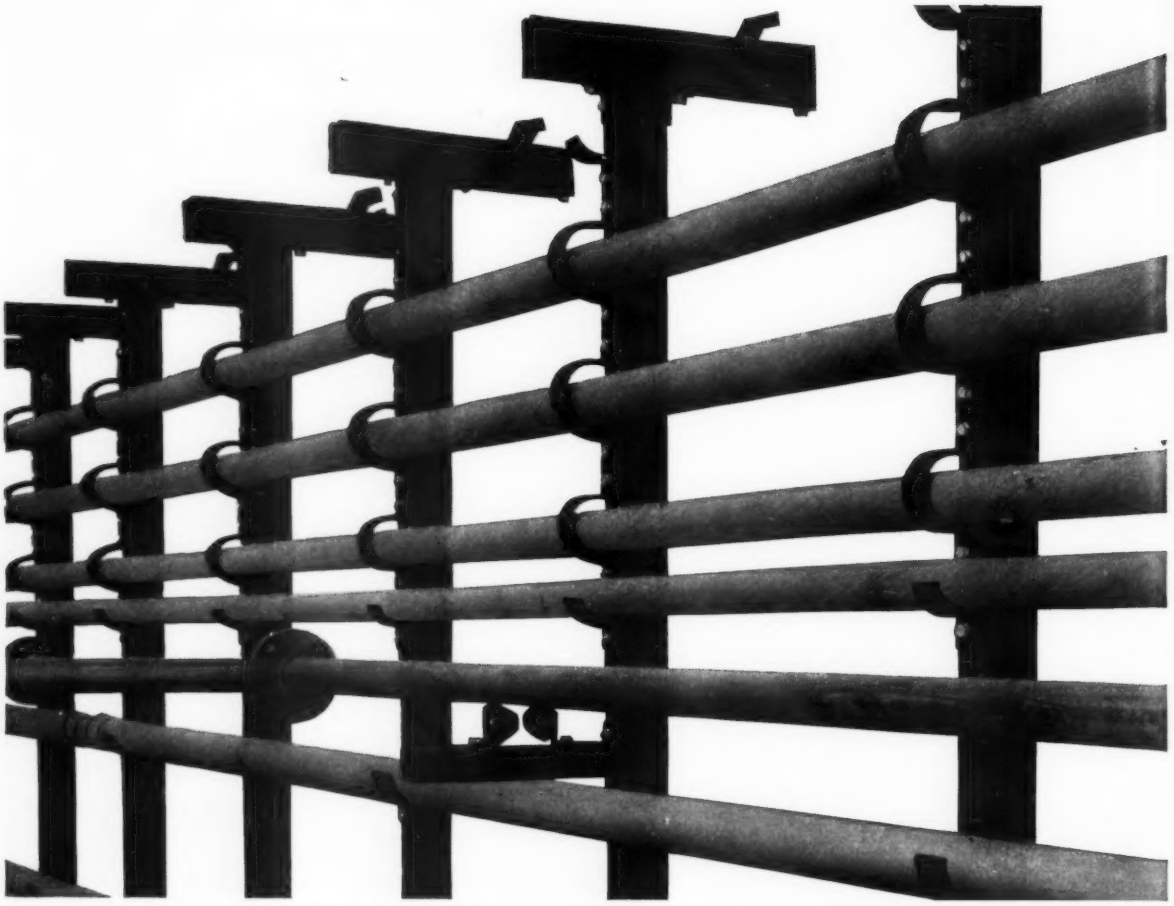

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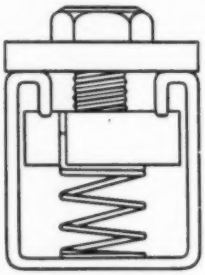

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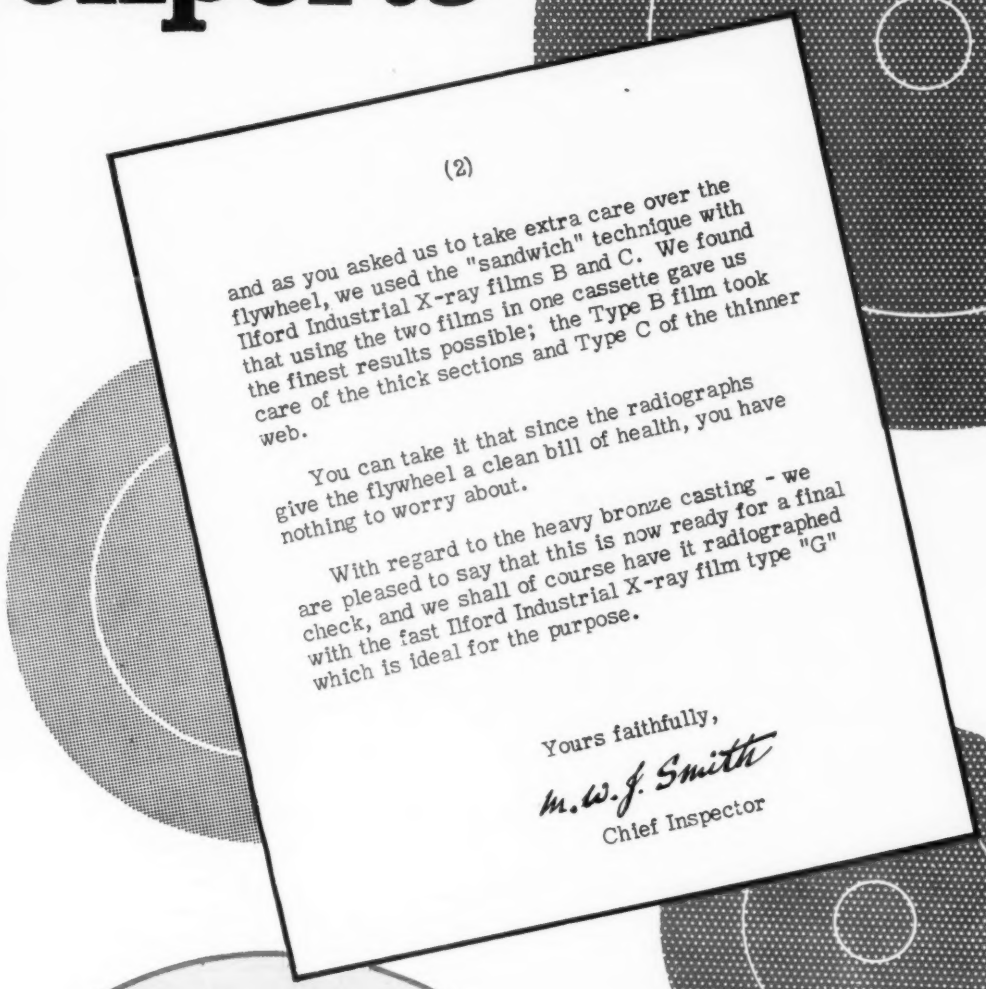

(2)

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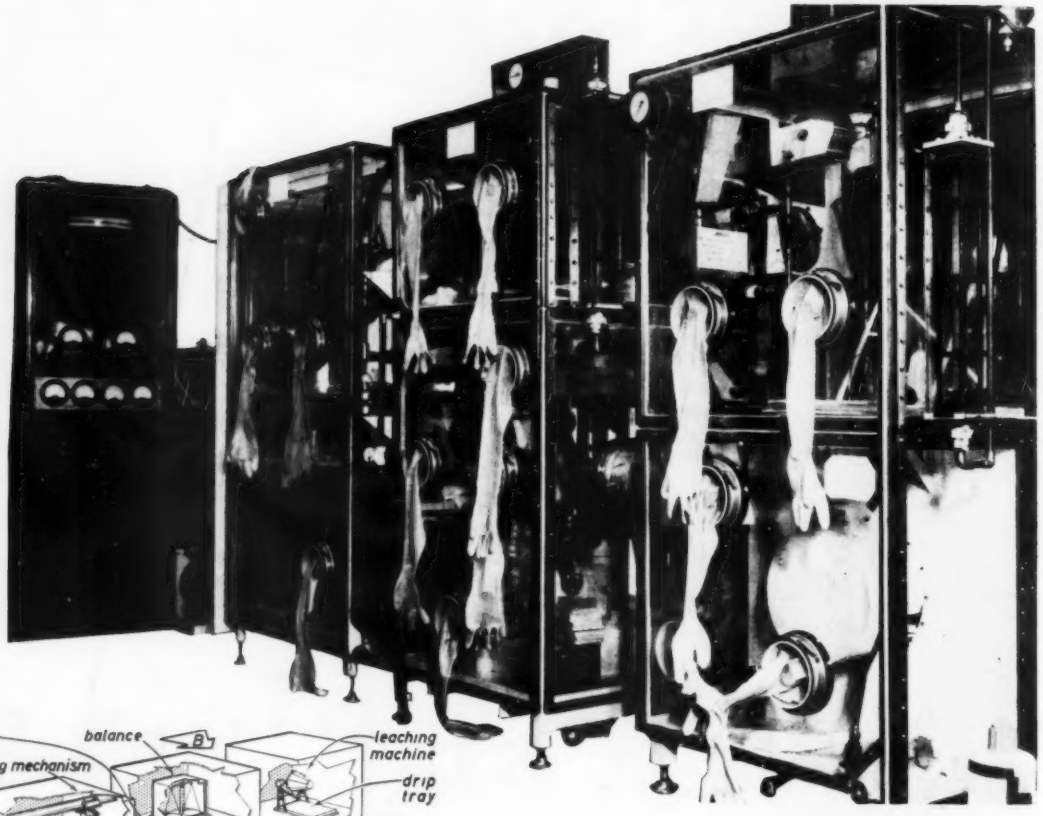
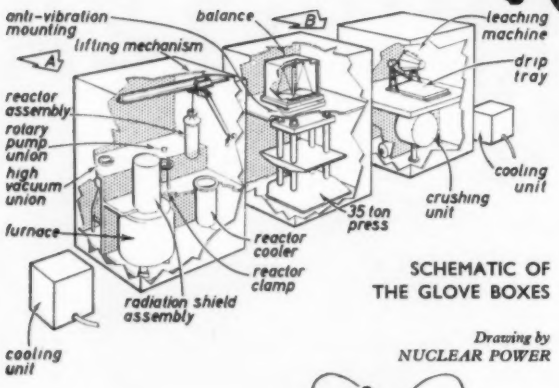


Photo by courtesy of A.E.R.E.

A SUITE OF GLOVE BOXES FOR EXPERIMENTAL PRODUCTION OF U-233 METAL



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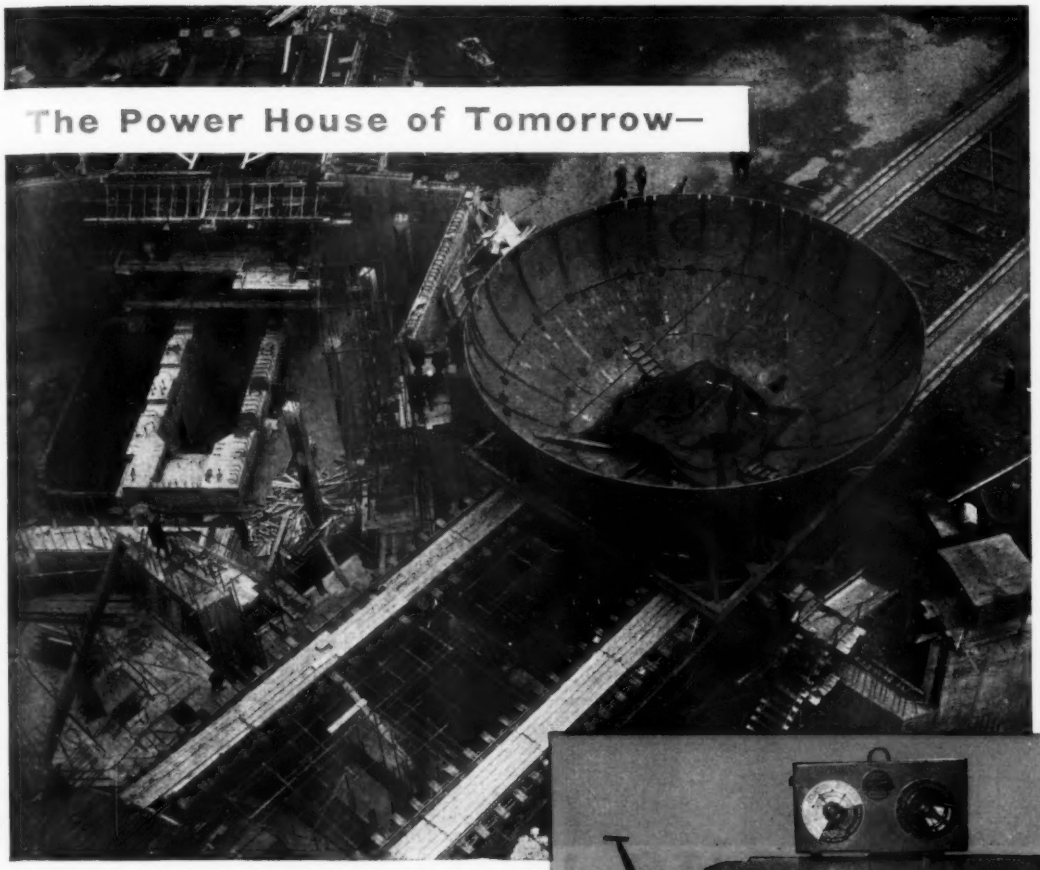

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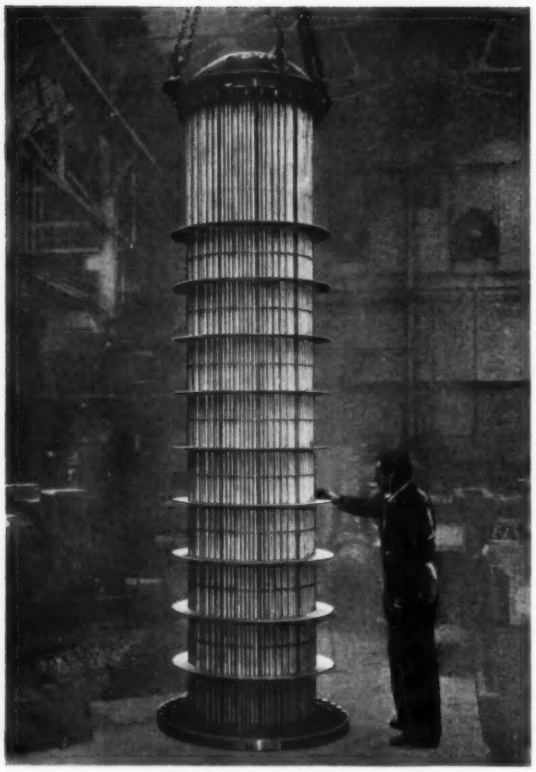

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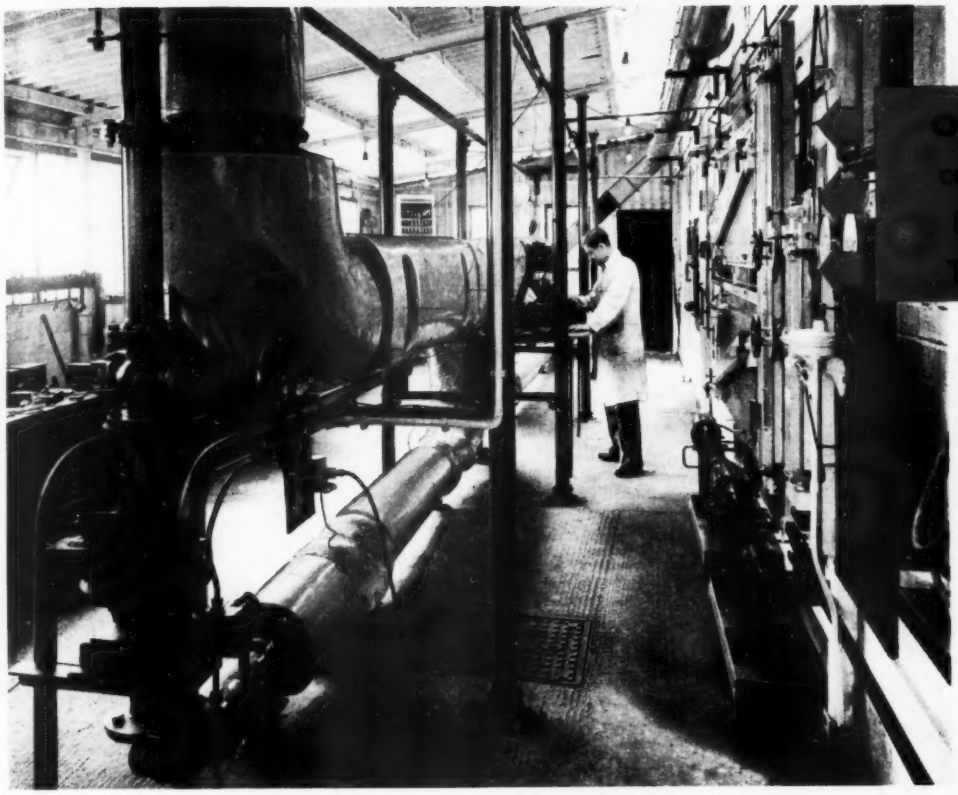

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Nuclear Power
THE JOURNAL OF BRITISH NUCLEAR ENGINEERING

FEBRUARY 1958 VOLUME 3 NUMBER 22

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Publishers Column

Carte du Jour

One day not long ago an important executive of a well-known firm of nuclear power station contractors visited our offices on business. During the course of conversation he said 'what I like about Nuclear Power is the way it's served up.' And that started us thinking. We had never really considered it this way before but it then occurred to us that we should regard ourselves as sort of chefs working in an editorial kitchen. Our raw material—our meat, fish and vegetables as it were—arrives usually in a pretty raw state, or at least only partly cooked, and our job is to peel and trim it, then see that it is done to a turn according to the prescribed recipe and finally serve it up with the appropriate sauces.

We know that most busy engineers and executives have far too much to read anyway although their jobs demand that they keep themselves fully abreast of developments in their field. Since in nuclear energy these fields are many, ranging from heavy piled foundations for power reactors to subminiature transistors, our menu has to be very long. But whether you want a snack or a full meal we aim to make them all as appetizing as possible so as to tempt appetites jaded by too much reading.

By its nature any sort of modern technology is a difficult subject and the kinds of articles our readers want are often quite hard going. Thus anything we can do to ease the sheer physical task of assimilating knowledge is well worth doing. This involves a great many resources of modern journalism not least of which is the avoidance of waste—waste of words, mainly. Dr Johnson said 'when you have written a passage you particularly admire, strike it out immediately.' Now Johnson was no great exponent of pithy writing except in his epigrams but his axiom is a must in this office. In addition our art and layout departments are imbued with the same spirit, to make the magazine as bright and easily read as is possible. In this way we save you time which, after all, is probably man's most precious commodity.

Regular readers will have noticed last month that we started a new feature 'Progress in Industry' which is continued in this number. During the course of a month we are invited—and invite ourselves!—to a great many firms where work of greater or less interest to nuclear energy is taking place.

Until recently such a regular feature was hardly justified owing to the scarcity of sufficient industrial stories with a clear enough nuclear appeal but now, with the big power station programme getting into top gear, more and more firms are finding something to talk about. We are glad to offer them the courtesy of our pages for recording these advances that are keeping Britain in the forefront of nuclear energy.

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SIR! LETTERS TO NUCLEAR POWER

Radiological recommendations

SIR: In your article on the Radiochemical Centre, Amersham (December 1957) it is stated that the installations conform with the latest recommendations of the Medical Research Committee and the International Commission on Radiological Protection. Our firm is interested in equipment for radiological laboratories and we would be very grateful if you could advise us how and where to obtain the recommendations.

AB Svenska Flaktfabriken, L. NILSSON
Stockholm, Sweden

▶ *The recommendations referred to are contained in supplement No 6 to the British Journal of Radiology, published by the British Institute of Radiology, 32 Welbeck Street, London, W1. It costs 10s 6d (post free).* *Ed.*

Misattributed achievement

SIR: I am writing to thank you for the excellent reporting of some speeches which I have made. I should, however, be grateful if you could publish in your next issue a short note to the effect that the item marked 'Harwell discovery' in column 1 on page 38 of the January issue is actually an account of a discovery made at the Oak Ridge National Laboratory, Tennessee, by Dr Weinberg and his team.

Harwell J. V. DUNWORTH

▶ *We apologize to Drs Dunworth and Weinberg.* *Ed.*

More on telemetering

SIR: The article by Mr W. Jervis in your January issue gave a most helpful introduction to the various pneumatic and electrical systems available for data-transmission in automatic process-control loops. The author's conclusion, that pneumatic schemes are at a disadvantage compared with electrical ones due to the much faster response and greater flexibility of the latter, suggest that a considerable expansion of his paragraph on 'Electrical Transmission' could form a most useful further contribution to your valuable journal. May we look forward to such a contribution in the not too distant future?

Radlett, BRUCE M. ADKINS
Hertfordshire

▶ *As a matter of fact this had occurred to us and we hope to carry an article on the subject next month. Ed.*

Ships—let's wait

SIR: In your January issue you describe the possibility of an atomic powered merchant ship; and amplify this in your editorial, saying that economics should be disregarded.

This may be possible for America and Russia, whose economics are extremely robust but with our smaller resources we should wait until it was a paying proposition.

Our maritime supremacy will not be regained by building expensive ships, which are only able to keep on the seas with the aid of a subsidy. We must wait until they pay dividends, and then throw everything we have into building them as fast as possible.

Highgate, R. H. MACDONALD
London, N6

▶ *The point we made was that while Calder Hall is not an economic proposition, its immediate descendants probably will be. We believe we cannot wait till others have proved the nuclear ship and then climb on their back—we must go it alone as we did with the power stations.* *Ed.*

Data sheets

SIR: I would like to take this opportunity of congratulating you upon the excellent quality of NUCLEAR POWER, and to ask you to include in future issues more of your excellent data sheets—particularly on reactor materials such as fissionable and fertile materials, canning materials, moderators, coolants, structure materials etc.

Didcot, S. B. HOSEGOOD
Berks

▶ *Data sheets already published in* NUCLEAR POWER *are:*
Microscopic cross sections of elements for thermal neutrons May 1956 Vol I No 1
Zirconium and Zircaloy II mechanical properties June 1956 Vol I No 2
Neutron diffusion formulae July 1956 Vol 1 No 3
Bessel functions December 1956 Vol 1 No 8
Beryllium—physical and mechanical properties October 1957 Vol 2 No 18
Another good source of data is the NUCLEAR POWER YEAR BOOK *and* BUYERS GUIDE. *Ed.*

Navy lectures

SIR: For the last two years I have been studying atomic energy and have given several lectures on nuclear power for peaceful purposes, including some to naval audiences. Having seen some of your coloured reactor drawings in Information Rooms in Naval Establishments, I wonder if you could supply me with copies for my own use.

Petty Officers Mess, A. C. FORD
Royal Naval Air Service,
Yeovilton, Somerset

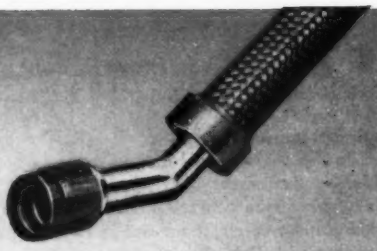
▶ *It's good to know that the Royal Navy is so interested in nuclear power—for peace as well as war. Demand for these large pull-outs has been overwhelming and some are completely sold out. However, we've sent Mr Ford what we still had.* *Ed.*

Visual aids

SIR: I am the Science Master of the boy's secondary school here. Recently I saw a splendid drawing of the Dounreay Fast Breeder Reactor published by NUCLEAR POWER at a local industrial firm. In connexion with my job such visual aids are most valuable, and I wonder if you could send me that publication and any other similar materials which would help me keep science teaching up-to-date.

Sowerby Bridge, JOHN THWAITES
Yorks

▶ *One of the greatest bottlenecks in this country to scientific advancement is the shortage of trained men and we are convinced that the rousing of interest in science at an early age is the key to a greater flow of technicians in the future. Thus* NUCLEAR POWER'S *series of large coloured cut-away drawings are indeed useful aids to this end. The drawing referred to by Mr. Thwaites was published in our June 1957 issue and measured 2ft by 3ft. In addition we have published the following in the same format:*
Berkeley Nuclear Power Station, April 1957
RWE Atomkraft Kahl Power Station, September 1957
Bradwell Nuclear Power Station, October 1957 *Ed.*



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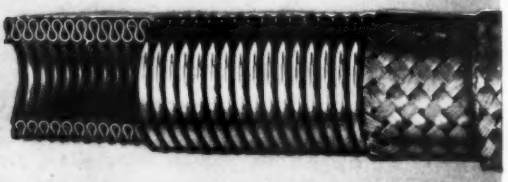
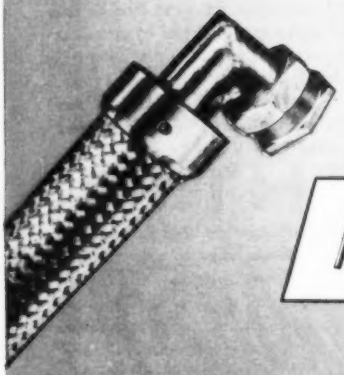


If you have a problem which could be solved by the employment of flexible hose—consult Power Auxiliaries Ltd. Specialists in this field, Power Auxiliaries Ltd., have built up extensive design experience which is readily available to all equipment producers.



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Nuclear Power
THE JOURNAL OF BRITISH NUCLEAR ENGINEERING
FEBRUARY 1958 VOLUME 3 NUMBER 22

Men wanted

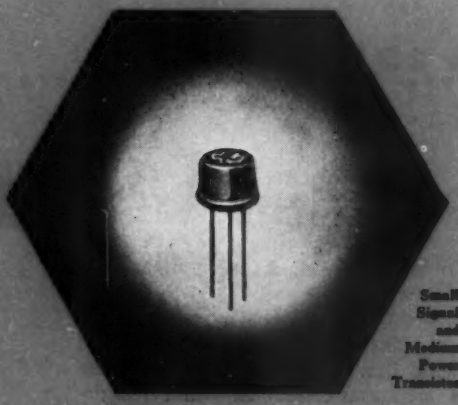
The report of the Fleck Committee on the organization of the Industrial Group of the Atomic Energy Authority, following the Windscale accident, finds little radically wrong with the Group —only that there is not enough of it for the work it has to do. Since the Risley organization was set up eleven years ago it has notched up a record of achievement of which it—and the whole country—can justly be proud and it is not surprising that the Windscale affair came as a great shock after such a long period of very difficult operations conducted with a remarkable record of safety and efficiency. In such circumstances it is all too easy to become blasé and cease giving atomic energy the respect it requires, so while it has never been suggested that the accident was due to negligence there is no doubt that a valuable cautionary lesson has been learnt.

It is a known fact that, for many men, plant operations are a bore and it is the task of the IG to ensure that in the Operations Branch all their round holes are occupied by round pegs. This is never easy and is management's daily problem throughout industry. Operations, however, are after all the AEA's main function in life and in a few years the electricity authorities also will be required to handle very large reactors indeed—far bigger than any the Authority are ever likely to build. Thus it is of vital national importance that public confidence in nuclear energy—which frankly has been shaken by the Windscale business—is restored and confirmed. Fail-safe philosophy and automatic control can do much, but in our present state of knowledge the ultimate safety of a nuclear plant must be vested in a thinking animal. In fact it is quite possible that these things can be taken too far and and it would be unwise to remove the last vestige of discrimination from the man on the job. That way lies boredom and danger. Incidentally it should be noted that probably the prime cause of the Windscale fire was not too much automatic control, but too little. How the Operations Branch is to obtain suitable men is another matter. It is suggested that staff should undergo tours of duty in the course of their training and this seems sound — provided of course that they are not allowed positions of real responsibility until they are ready, willing and eager to accept them. The accident has abundantly confirmed the wisdom of the Government's power station siting policy and in this connexion one immediately thinks of Dounreay. Here is the most advanced reactor in the world nearly ready for action, not to mention the enriched fuel processing plants and the critical assembly laboratory. There is clearly much that could go wrong with these works and the Fleck Committee have done well to recommend that the whole set-up be critically examined, once again just to make absolutely sure that adequate qualified staff is available to the new Director who is to be appointed.

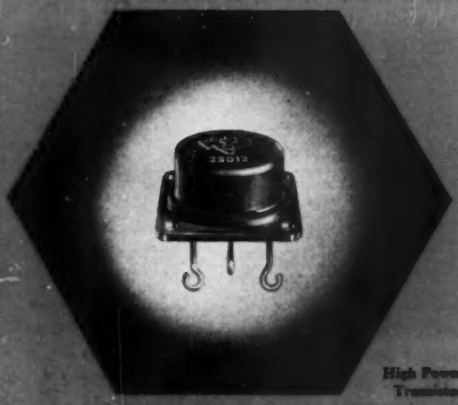
The Industrial Group, when it was constituted in its present form in 1954 with the passage of the Atomic Energy Act, largely, but not quite, sloughed off its Civil-Service skin and emerged looking something like a commercial concern. If the Fleck recommendations are accepted and implemented this process will go even further, with the cultivation of leadership at all levels and the assumption of appropriate responsibility. One wonders in fact whether in the course of time some new sort of organization altogether might emerge—one perhaps similar to that in the United States, where atomic energy production plants are operated by private companies for the Atomic Energy Commission. Certainly the IG still is a perfectly sound way of doing the job we want at the moment, but as the commercial power stations begin operating it may well be better from a national point of view for the Government to relieve itself of responsibility for making and reprocessing fuel elements and hand over the whole business to industry.

HERE and NOW TEXAS

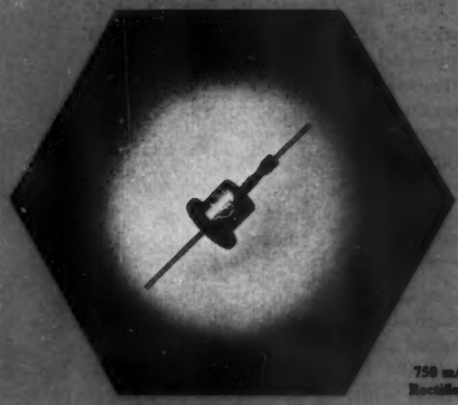
HAVE THE RANGE...



Small Signal and Medium Power Transistor



High Power Transistor



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Now it can be told

Important news on thermonuclear research both in Britain and the United States was released simultaneously in the two countries at 1800 hrs GMT on Jan 24. Since 1956, said an AEA statement, issued on Jan 15, there has been a continuing and complete exchange of information between the Authority and the US Atomic Energy Commission and the collaboration has included consultation on the timing of the announcement.

Anglo-US cooperation has covered classified as well as unclassified work and a recent revision of the joint classification rules has, said the Authority, made possible this release. Before the Christmas recess Lord Privy Seal R. A. Butler said he would release details of this work early in the new year (*Worldview*, January 1958).

It is understood that the British contribution to the joint release will be mainly concerned with work on the ZETA, Harwell's thermonuclear device, in which temperatures of several million degrees have already been reached. A full report of the disclosures appears elsewhere in this issue.

Shortage at the top

Two of the three committees appointed by the Prime Minister after the Windscale accident have now published their reports—on the organization of the AEA's Industrial Group, and on the control of health and safety in the Authority as a whole. Conclusion common to them both is that there is considerable shortage of experts in senior posts in these two fields and some changes in organization are recommended to remedy this. Full details of the Fleck-Kearton-Penney report on the Industrial Group and the Operations Branch in particular, are given on p71-2 of this issue.

No fundamental weaknesses in the Authority's health and safety organization were found by the second committee, which comprised Sir Alexander Fleck, of ICI, as chairman, Sir George Barnett, chief inspector of factories, Dr D. J. Carter, chief alkali inspector of the Ministry of Housing and Local Government, C. F. Kearton, director of Courtaulds and part-time member of the Authority, Sir William Penney, director of AWRE, and Prof B. W. Windeyer, Professor of therapeutic radiology in London University. The committee was particularly conscious that the Windscale accident brought to the surface the latent public anxiety about the hazards of nuclear energy. 'The public may be assured, however,' they say 'that the precautions which are applied are extremely elaborate: the underlying conception is to aim to err on the side of caution and within the limits of existing knowledge, no chances are taken.' Operating procedures and codes of practice must, within the limits of human ingenuity, be proof against human failure. In general the committee is satisfied that the Authority's policy has been governed by these principles, but the Windscale accident showed that their organization and their link with other government departments concerned with nuclear health and safety is inadequate. Twelve recommendations are given in the report to make good the deficiencies.

More training To overcome the shortage of specialists in senior posts, the committee recommends that the Authority should establish a national training centre for health physics and nuclear safety staff under the general supervision of the Research Group. Courses should be graduated to suit all levels and cover not only problems of radiation hazards but also health and safety aspects of the use of isotopes in medicine, agriculture and industry. Government departments should be directed to ensure appropriate training is given in public services and industries for which they are responsible.

They endorse the Authority's decision to establish a committee of the Atomic Energy Executive to be responsible for the overall supervision of health and safety matters, and also approve the new health and safety organization at Risley and the concept it contains of an Authority Safety Branch. Management of health and safety in the Industrial Group factories should, they consider, be integrated into a single section responsible to the General Works Manager.

Public statements Present procedures for the publication of information about accidents should, in the committee's opinion, be reviewed with a view to giving a prompt account of such occurrences with 'as much detail as may be appropriate.' (The interval between the realization that the Windscale incident was serious and the public announcement was in the region of 24 hours.) They recommend that site emergency procedures in all the AEA establishments should be brought to a uniformly high standard and coordinated so that the whole technical resources of the Authority may be used in the event of an emergency. Collaboration between the three groups should also be improved on problems concerned with criticality.

Cabin in the Sky

Night view of Berkeley (275MW) power station site, taken just one year after ground was broken in January 1957, shows its two reactors rising rapidly from their foundations. Inside the thermal shield of No 1 reactor (nearest) work is already far advanced on the building of the 50 ft dia., 80 ft high pressure vessel in 3 in. steel plate. To keep the weather out the shield is closed by a temporary 'dustbin lid' while right above, lit up, is the cabin of one of the two tower cranes. Down the road at No 2 reactor the thermal shield is already high and work is just commencing inside on the pressure vessel. Number 1 is due operative by end-1960: No 2 six months later

CEGB takes over

On January 1 the nationalized industry that is responsible for electricity generation and distribution in England and

Wales commenced a new era. On that day, as a result of the 1957 Electricity Act, the Central Electricity Authority was dissolved and the new Electricity Council and Central Electricity Generating Board took over. The main object of the change is to effect a degree of decentralization and give greater autonomy to the Area Boards. The Council's job is to act as an overall coordinating body between the Generating Board and the Area Boards. Chairman of the Council, appointed by the Minister of Power, is Sir Henry Self and it has 19 other members, including the chairmen of the Generating and Area Boards.

The Generating Board, under the chairmanship of Sir Christopher Hinton, is to produce electricity and distribute it in bulk to the Area Boards. But under the new act the Areas now have powers to generate their own with approval from the Minister of Power. The Generating Board consists at present of 9 members but on April 1 it will be joined by Leonard Rotherham, now Director of Research and Development

ROTHERHAM
Atoms to electricity

at the AEA Industrial Group headquarters, Risley.

Graduating from University College, London, Mr Rotherham was a physicist at Firth Brown Research Laboratories in Sheffield from 1934-46. He then went to the Royal Aircraft Establishment as Superintendent of the Metallurgy department and in 1950 he became Assistant Controller, Atomic Energy Division, Ministry of Supply. In 1954 he went to Risley under Sir Christopher Hinton and now follows him on to the Generating Board.

The existing Generating Divisions will continue as operational management units and they will be grouped under Regional Directors as follows: 1. North Eastern and Yorkshire, 2. Midlands, and East Midlands, 3. Eastern, London, and South Eastern, 4. Southern, South Western, and South Wales, 5. North West, Merseyside and North Wales.

The existing technical organizations will remain under the Divisional Controllers, but accountancy and some administrative functions will gradually be brought together at the regional offices. Each region will have a Regional Executive Committee for its administration within the broad policy rulings laid down by the Central Board.

The development of the industry is such as to make it impossible to secure a uniform load on the construction staffs of the eleven Divisions, or even the five proposed regions; it is therefore planned to establish three separate 'Engineering Project Offices' as follows: 1. North—possibly at Leeds or Manchester—working for the North West, Merseyside and North Wales, North Eastern and Yorkshire areas, 2. Midlands—possibly at Birmingham or Nottingham—working for the Midlands, East Midlands and South Wales areas, 3. London, working for the London, Eastern, South Eastern, Southern and South Western areas.

The project offices will have flexible boundaries to enable them, when convenient, to undertake projects in adjoining areas. They will undertake construction of new stations or major extensions to existing stations and construction of the associated switching stations, and will deal with nuclear as well as conventional power stations.

Hunterston water supply

Water consumption at the GEC Simon-Carves nuclear station at Hunterston is estimated at between 150,000 and 200,000 gallons per day. To meet this demand special arrangements are to be made by the South of Scotland Electricity Board and the Ayr County Council. New facilities will include a 3 million gallon storage tank and several 8 in. mains, two of which will have to cross the Ardrossan-Largs railway and road. Estimated cost is in the region of £78,000 of which the Board will pay £60,000; work is due to begin in the near future.

Japanese order soon?

A group of nine Japanese engineers and scientists recently visited English Electric's works at Whetstone near Leicester, headquarters of the English Electric: Babcock & Wilcox: Taylor Woodrow atomic power group. The mission, headed by Dr T. Ipponmatsu, vice-president of the Japan Atomic Power Company, came for discussions with a number of British atomic power groups and various UK governmental bodies on the possibility of purchasing an atomic power station of the British type with an output of about 150 eMW. The cost is estimated at between £M20 and £M30.

In considering atomic power one problem the Japanese have to consider is the to earthquakes. The mission has to satisfy well-known susceptibility of their country itself that the British type of reactor can be adapted to withstand earthquake shocks and that no anxiety will be caused to a public understandably sensitive to the dangers which may arise from a seriously damaged reactor.

The Japanese advance party investigated the various designs of the British groups, and then reported to a larger Japanese mission which arrived in this country on Jan 18. Following this, the two teams joined in further talks with British industry. It is expected that a contract with a British group will be signed in time for construction to begin in October of this year.

Citrine joins UKAEA

Lord Citrine, chairman of the Central Electricity Authority until its dissolution at the end of 1957 when the new Electricity Act came into force, has been made a part-time member of the United Kingdom Atomic Energy Authority in succession to Sir Luke Fawcett. He con-

CITRINE
Electricity to atoms

tinues his connexion with the electricity supply industry since he has also been appointed part-time member of the Electricity Council.

So far no appointment has been made on the Atomic Energy Authority to the important seat of member for engineering, vacated last autumn by Sir Christopher Hinton on his transfer to the Central Electricity Generating Board. The Fleck committee on organizational problems of the AEA Industrial Group (see p 71) recommended that this be filled as soon as possible.

Harwell chief offered IAEA post

Post of deputy director-general of the International Atomic Energy Agency has been offered to Dr Henry Seligman, head of Harwell's isotope division, to be in charge of the Agency's department for

SELIGMAN
Isotopes to . . . isotopes?

isotopes and research. This means that Dr Seligman would be seconded from the UKAEA and be absent from Harwell for about six months. At the time of going to press, he had not definitely decided whether to accept the appointment for this reason. There will be four deputies to director-general Stirling Cole—other three are Dr Paul Jolles (Switzerland) to head the administration department, M Hubert de Laboulaye (France) to head technical affairs, and Prof V. V. Migulin (Russia), education and information.

Further news of Dr Seligman is his inclusion in the New Years Honours List—he is made an OBE.

INTERNATIONAL

Wise man is Euratom chief

After lengthy discussion, the Foreign Ministers of the six European Economic Community countries have finally decided on the members of the high commissions of the Common Market and Euratom. Louis Armand, chairman of the French CEA and of the State Railways and one of the three wise men, is nominated president of the Euratom commission. Vice-president is Enrico Medi, director of the National Institute of Geophysics at Rome University and a member of the Italian National Committee for Nuclear Research. Members are P. de Groote, vice-chairman of the Belgian atomic energy commission and head of the study centre for nuclear energy, Dr Heinz Krekeler who trained as a chemical engineer and is now German ambassador in Washington, and E. M. J. A. Sasson, a member of the Dutch Upper House.

No decision on the headquarters of the two organizations was reached. It was unanimously agreed, however, that they should both be centred at one capital, but it appears that the Ministers made no progress in deciding which it should be. They are to meet again before June 1 to try to reach a final decision.

OEEC chemical plant agreed

The Council of OEEC adopted on Dec 20, 1957, the statute of the European Nuclear Energy Agency and signed a convention on security control. At the same time twelve member countries of the Organization signed an agreement setting up a first joint undertaking, the European Company for the Chemical Processing of Irradiated Fuel—EUROCHEMIC. These decisions are the outcome of the work done in the course of the year by the Steering Committee for Nuclear Energy under the chairmanship of Professor Nicolaidis.

The European Nuclear Energy Agency will be a specialized agency established as from Feb 1, 1958, within the framework of OEEC and under the authority of its Council. The objective of the Agency is to further the development of the production and uses of nuclear energy for peaceful purposes through technical cooperation among the countries of Western Europe.

Its functions will be to promote the establishment of joint undertakings between those countries, discuss their research and production programmes for nuclear energy, study their requirements for raw materials and capital equipment, promote the liberalization of trade in these products, develop facilities for the training of specialists and help to finalize and harmonize national legislation, in particular as regards the safeguarding of public health, prevention of accidents, third-party liability and atomic risk assurance.

When carrying out these tasks, the Agency will take into account work done by the other international organizations concerned and will, as far as possible, call on them for assistance. It is provided in particular that in view of the special powers attributed by the six countries to Euratom, the Agency will conclude an arrangement with the European Commission as soon as possible, in order to establish close cooperation with Euratom.

Joint chemical plant At the same time as these general decisions were adopted by the Council, twelve member countries of the Organization reached an agreement to set up a first joint undertaking, the EUROCHEMIC Company. The purpose of this company will be to build and operate a plant for the chemical treatment of irradiated fuel and extraction of plutonium, which will be erected at the Nuclear Research Centre at Mol, Belgium. With a capacity for treating approximately 100 tons of natural or slightly enriched uranium per year, the plant is expected to cost about £M5 and will probably be in operation in 1961. It is foreseen as a pilot plant for a much bigger installation to be built in 1964-5.

This undertaking is constituted as a European company with a capital of about £M8½ set up under an international convention with the participation of governments, public institutions and semi-public or private undertakings. Certain governments have stated their intention of transferring their initial participation to private industry. The two biggest shareholders will be France and W. Germany. A start will be made on the preparatory work at Mol for the erection of the plant on the signing of this convention without waiting for its ratification.

Other joint projects Work is in progress to set up two other European establishments. A project is under discussion for the joint operation of the boiling water reactor built at Halden, Norway, by the Norwegian Institute for Atomic Energy. Secondly, the establishment of a homogeneous aqueous reactor at the new British research centre at Winfrith Heath is also under study.

The steering committee also agreed at its last session to study the possibilities and the economic conditions for the production of heavy water in Iceland by using geothermic energy which provides an abundant source of heat at exceptionally low cost.

CANADA

No hurry for Hydro

Canada is unlikely to have full-scale nuclear power stations before 1966 and even then they are not expected to be competitive with imported coal—let alone hydro. This is put forward in a sponsored article by Mr Matt Ward, acting director of planning of Ontario Hydro-Electric Commission in a recent issue of the Canadian journal *Modern Power and Engineering*. Mr Ward said it was at present impossible to give any firm cost estimates for nuclear stations but it was at least certain that any plant built today could not possibly compete with conventional thermal power. In figures, a 300MW coal-fired base-load station installed in 1961 will generate 7000 hours a year at 5·14 mills/kWh in terms of the 1957 dollar: by 1980, this is expected to drop to 4·7 mills (a mill is one tenth of a cent). However, if this were the only type to be built, it would mean importing 30 million tons of coal a year, costing $M270, from the United States.

By the time the St Lawrence Seaway scheme is finished in 1960 there will be no sizeable hydro sites of economic value left to develop in Ontario, so from now

on Ontario Hydro must lean more and more on thermal power.

GCR not economic There seems little, if any, hope of the British type of gas-cooled reactor proving economic, according to Mr Ward. Taking Sir Christopher Hinton's figures from his 1957 Stockholm lecture (*Worldview* April 1957) for costs of this type of plant, he translates them into Canadian terms. Allowing no plutonium credit and assuming 80 pct load factor, the cost of electricity from these stations in Ontario is estimated as:

1960	1970	1980	1990
10·75	7·26	5·53	4·27 mills/kWH

As opposed to these figures, Mr Ward quotes the following for heavy water moderated and cooled reactors of the type being developed by Atomic Energy of Canada:—

1965	1975	1985	1995
5·94	4·01	3·06	2·36 mills/kWh

These are exclusive of development charges but even so, Mr Ward concludes, there is no hope of nuclear beating coal power before 1968, even for base-load generation.

No matter how attractive the future of nuclear power might be, and in spite of the fact that the fuel is indigenous to Ontario, the Hydro Board spokesman said the cost differential is so great that they cannot at this time pass it on to the consumers. Operational reliability, too, is a factor that has not been proved. Despite these factors militating against nuclear power for Ontario, Mr Ward is confident it will come and that it will not be necessary to wait until absolute superiority has been demonstrated on a full-scale plant: some loss must be accepted initially. By the late 60's the Hydro Board official sees the beginning of a period of rapid expansion: by 1980 (estimated demand 22,000MW) it is possible that one-third of the Board's requirements will be met by nuclear plants.

Transition period Thus it is apparent that Ontario is in no particular hurry about nuclear power and is planning a fairly leisurely transition period extending over a decade or more. Mr Ward in fact indicated progress taking place in three stages: 1. development stage—proving dependability; 2. confidence stage—competition with conventional fuels; 3. coming of age stage—nuclear power in the lead for base-load. In connexion with the last stage, Mr Ward said unless economical nuclear peaking plants could be developed, conventional thermal plants would still have a great part to play.

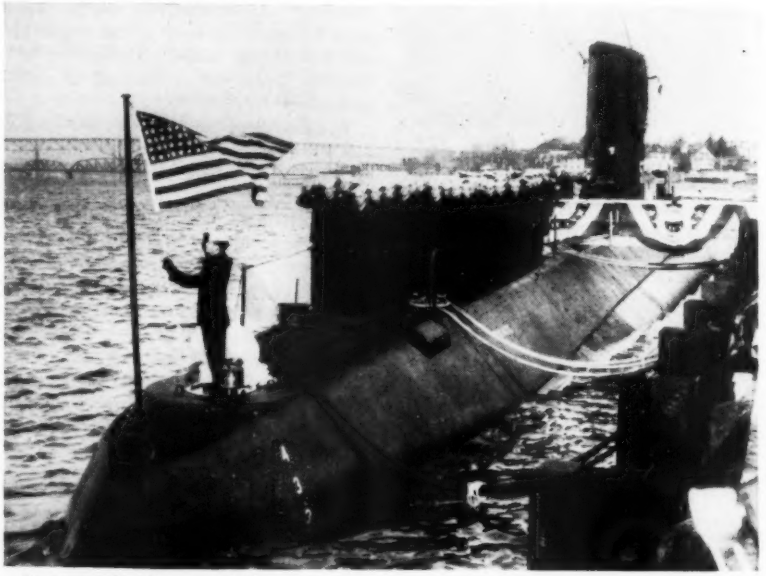
ITALY

Government signs with UKAEA

A ten-year cooperation agreement on the peaceful uses of atomic energy was signed in Rome on December 28 between Britain and Italy. This is the first comprehensive agreement to be offered by Britain to another country. It follows the AGIP Nucleare-Nuclear Power Plant Co deal announced in November (*Worldview*, December) providing for seven years technical cooperation and the building of a 200 MW power station in northern Italy. This would not have been possible without the inter-governmental agreement which provides for fuel supplies and processing. Under the new pact the Italian government agree to exchange unclassified information and the UKAEA also undertakes to give assistance in the supply of research and power reactors from Britain, to help in the design, construction and operation of facilities for fuel manufacture and processing in Italy, to provide training facilities for Italian students and trainees.

Safeguards are incorporated to ensure that nuclear materials and equipment supplied are used only for peaceful purposes. Transfer to Euratom of the facilities given to Italy can only be done with Britain's specific consent.

UNITED STATES



First production model

The Stars and Stripes is run up the foremast as the US Navy's third atomic submarine—the USS 'Skate,' of 2190 tons—is commissioned at Groton, Connecticut, just before the turn of the year. A direct descendant of 'Nautilus,' but considerably smaller, she, too, was built at Groton by General Dynamics' Electric Boat Division and engined with a pressurized water reactor by Westinghouse Electric. 'Nautilus' cost about $M90: 'Skate,' only about half this

Two new proposals to AEC

Definite proposals to the AEC for their homogeneous power reactor have been filed by the Pennsylvania Power & Light Co and Westinghouse Electric Corpn. Work started on this concept in 1955 and the present move is in response to the AEC's invitation of Jan 1957 for third round proposals in its Power Reactor Demonstration Programme. This design is for a single-region thorium-uranium slurry reactor with an output of between 70 and 150eMW. Its sponsors ask the AEC to contribute $M7·3 for further research during 1958-9 and for a decision regarding actual construction to be made in Dec 1959. Given this, completion is envisaged by the end of 1963. Already the two organizations have invested $M5·5 in the project and set up a $M2 research facility. Recently Baltimore Gas & Electric Co joined this group. No site has yet been named.

Another third round proposal received by the AEC is for a gas-cooled heavy-water-moderated reactor—put forward by the East Central-Florida West Coast nuclear group. An earlier proposal for this type of reactor—a natural uranium unit with 136eMW output based on the Savannah River plutonium production reactors—was rejected by the Commission as not being acceptable as a basis for negotiation.

The new proposal is for a much smaller reactor of 50eMW output and would be regarded as the forerunner for a future 200eMW plant. It will use the pressure tube principle by means of which the moderator is not under pressure. The prototype model would use slightly enriched fuel but the bigger one could operate on natural uranium. Under the proposal the Commission and the companies would share equally the cost

of research and development and the Florida West Coast group, on whose system the plant would be built, would finance its construction and operate the station when it is built. Completion is foreseen as sometime between June 30, 1962 and June 30, 1963. The design firm for the project is Walter H. Zinn's General Nuclear Engineering Corporation of Dunedin, Florida, and the other members of the group are some 17 electric supply companies.

Battelle form new division

A reactor physics division has been established at Battelle Institute, Columbus, Ohio. One of its primary functions is to coordinate the increased volume of reactor research now under way at the Institute. Under the direction of Joel W. Chastain, Jr, the physics division will conduct research in four major fields: radiation effects and exponential experiments utilizing Battelle's 1 MW reactor; reactor design development through critical experiments; theoretical reactor design analysis; heat-transfer studies. Chastain points out that Battelle reactor physics research is complemented by Institute research on reactor materials and metallurgy, fuel-element development, and radiochemistry-research with a volume of more than $M5 in 1956.

Advanced instruments only

The European market for simple nuclear equipment is now largely being supplied from France and Germany, and America can now hope to supply only the latest and most advanced instruments. This was stated by Dr Ernest H. Wakefield, president of Radiation Counter Laboratories, Skokie, Ill, recently when he announced trading results for the period July-Nov 1957. Some 23 pct of RCL's products were exported, he declared, most of them being complex instruments not available in Europe. American instruments, he said, were of the highest quality but the gap between them and foreign competitors had noticeably shrunk in the last year.

Army to try gas turbine

Ground breaking took place recently at the Army's Research and Development Laboratories at Fort Belvoir, Virginia, for a closed cycle gas turbine test facility. Aerojet General Corpn won the contract against 42 other bids. The system will use nitrogen as the working fluid and this will be raised to 1000°F in an oil-fired heater simulating a reactor. The gas will then be expanded through a two-stage axial-flow turbine coupled to a two-stage centrifugal compressor and an electrical generator. Power will be dissipated to an immersion heater. The turbo-compressor will be by Fairchild's Stratos Division.

WORLDBRIEFS

Constructional work on the 12MW heavy water research reactor—FR 2— at Karlsruhe started recently. The December 1957 issue of the magazine *Die Atomwirtschaft* (London agents—*Nuclear Power*) is almost entirely devoted to a series of articles on the reactor.

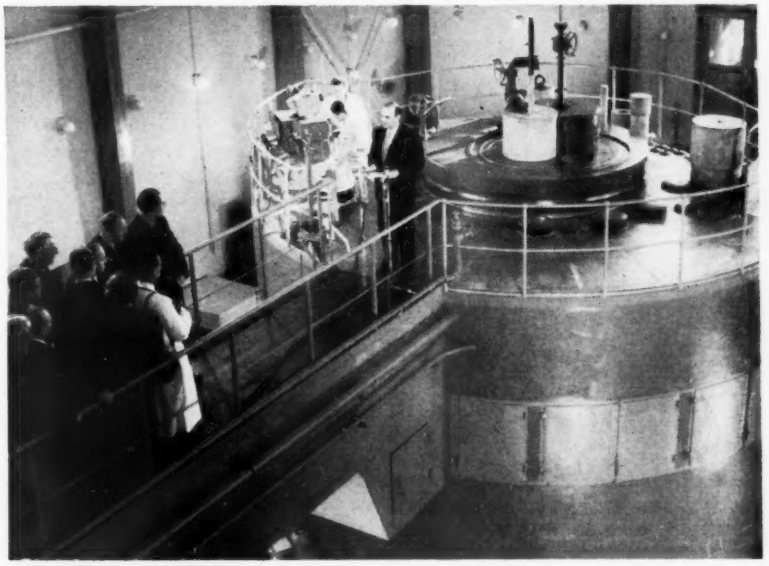
Agreement has been reached on technical assistance on non-military reactors between Westinghouse Electric Corp and the Siemens organization in W. Germany.

United States Atomic Energy Commission has moved into its new headquarters at Germantown, Maryland, some 27 miles from Washington.

Two nuclear ships are to be built in Japanese shipyards this spring; an 80,000 ton deadweight tanker, powered by a PWR, in Yokohama, and a 20,000 ton gross liner in Kobe.

International code of safety regulations for handling and transport of fissionable material is to be drawn up by scientific study group of IAEA. Chairman of the group will be Prof Gunnar Randers, managing director of the Norwegian-Dutch Joint Establishment for Nuclear Energy Research.

Power plant of the Russian nuclear-powered ice-breaker, the *Lenin*, is unequalled by any other machinery of its kind, claims *Leningradskaya Pravda*. Main electric motor is 20,000 h.p.



East Germany's first

On December 16, 1957, the German Democratic Republic's 2000 kW tank reactor officially went into operation at the Central Institute for Nuclear Physics at Dresden. Here the Director of the Institute, Professor Barwich, speaks at the opening ceremony; Prime Minister Otto Grotewohl was among the guests. Of the light-water-cooled-and-moderated type, the reactor will be used mainly for the production of isotopes

SORIN—Italy's Società Ricerche Impianti Nucleari, of Milan—has ordered a 1MW pool reactor from AMF, New York. Cost is $489,000.

Argonne's fast breeder reactor—EBR 1—went critical recently with its Mk III core. It will be used for experiments on fast reactor stability. The Mk II core melted out last year in a power excursion.

Construction is to start soon of a new reactor at the National Reactor Testing Station, Arco, Idaho. Known as TREAT—Transient Reactor Testing Facility—it will be operated by Argonne's Idaho Division and used to test breeder fuel elements to destruction in conditions simulating a reactor accident.

British firms in the electronic and nuclear fields will take part in the fifth international congress of electronics and atomic energy in Rome from June 16 to 30.

Reactor Centrum Nederland, The Hague, is to get a 20MW tank-type materials-testing reactor from ACF Industries, New York.

Copenhagen shipyard, Burmeister and Wain, have appointed Prof Sven Werner of Aarhus University, as technical adviser on nuclear ships.

New president of CERN, the European Centre for Nuclear Research, is M. François de Rose, a member of the French AEC. He succeeds Sir Ben Lockspeiser who has completed the statutory 3-year term of office.

Five months ago Harwell obtained temperatures of five million degrees on a pinched gas discharge machine. Details of these experiments have just been declassified

THERMONUCLEAR POWER

ZETA shows way ahead

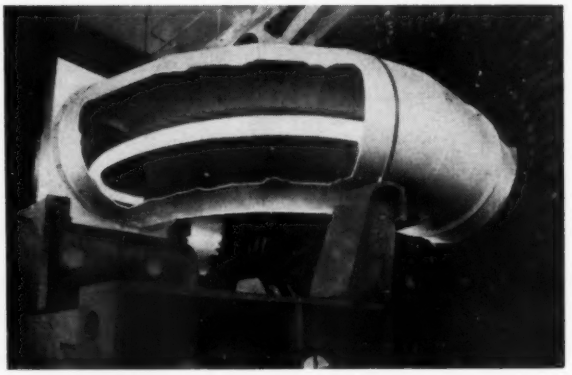
Four-stage development expected

IT NOW SEEMS CERTAIN that there is no fundamental physical reason why power from thermonuclear fusion of light elements should not be achieved, although the development to a practical stage is not likely to be easy or rapid. Results of several years' work in laboratories both in this country and in America were declassified simultaneously on Jan 24 and announced at Harwell. Generally, they confirm previous unofficial reports.

In Britain thermonuclear work since 1951 has been concentrated at the Atomic Energy Research Establishment, Harwell, in a team lead by Dr P. C. Thonemann and at the Associated Electrical Industries Research Laboratories, Aldermaston, under the direction of Dr T. E. Allibone. At Harwell, the latest apparatus used is ZETA; at Aldermaston a somewhat similar device known as SCEPTRE III is used.

ZETA is a toroidal or doughnut-shaped aluminium tube 1 metre bore, 3 m mean diameter and 1 in. thick. This is linked by the iron core of a large pulse transformer which is supplied from a battery of 52, 31 mFd capacitors in parallel capable of storing 500,000 joules of energy. The toroidal tube is fitted inside with a coaxial liner of aluminium $\frac{1}{8}$ in. thick, cooled by water coils. The purpose of this is to keep the discharge away from the main doughnut. The whole system is filled with deuterium at a pressure of about 10^{-4} mm of mercury, an auxiliary vacuum system maintaining the vacuum in the space between the doughnut and the liners. In order that the gas may be made conductive it is ionized by a mild radio-frequency discharge and thus forms a secondary short-circuited coil to the primary windings.

When a pulse is applied to the primary windings a current of about 200,000 amps is induced in the partly ionized gas. This completely ionizes it and pinches it into a tight filament or plasma. The current in the gas lasts for about 3 or 4 thousandths of a second and the pulse is repeated every ten seconds. In order to prevent instability of the plasma, or wriggling, a steady axial magnetic field is applied by a series of coils wound round the torus. By this means, the field can be varied up to about 400 gauss. In addition, the fact that the torus has thick metal walls also contributes to the stability of the plasma, for if it approaches the wall an eddy current is induced locally which has the effect of repelling the gas filament. It is this combination of axial field and eddy current repulsion which is one of the main features of ZETA'S success.



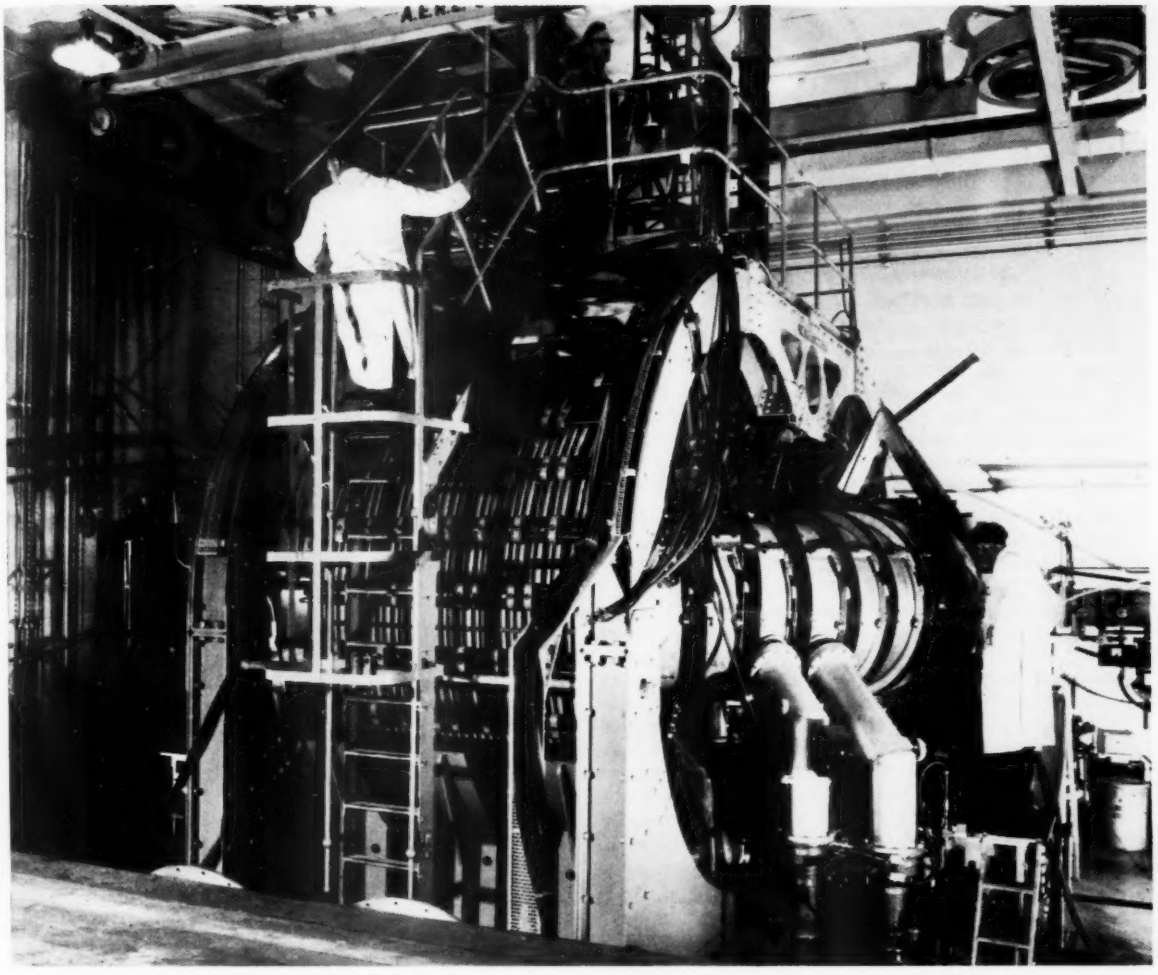
THE THERMONUCLEAR FLAME The Harwell ZETA consists of a 1-metre bore aluminium doughnut in which very heavy current pulses are produced. These squeeze the contained low-pressure deuterium gas into a pinched plasma at a temperature of up to five million degrees. This artist's impression shows how the gas plasma or 'flame' is kept away from the tube walls. Coils that do this are not shown

The reaction studied on ZETA is that using deuterium alone. There are actually two—both of equal probability:

$$H^2 + H^2 \rightarrow p + H^3 + 4\ MeV$$
$$H^2 + H^2 \rightarrow n + He^3 + 3{\cdot}25\ MeV$$

The thermonuclear reaction is brought about by raising the temperature of the deuterons until their energy is sufficient to overcome the coulomb repulsion barrier, and, for this to happen, temperatures of the order of at least M2°C are needed: for a net gain of energy this must be increased by at least two orders of magnitude. The test for a thermonuclear reaction is the detection of the neutrons produced in the second of these, but neutrons may also be produced by other fusion reactions such as the collision of an electrically accelerated deuteron with a stationary nucleus. It is easy to detect the neutrons, but difficult to verify whether or not they are genuine thermonuclear ones. A thermonuclear fusion is one between a pair of uniformly hot nuclei—it is due to temperature alone.

ZETA was started up on Aug 12, 1957 and on Aug 30 it was first operated under conditions where thermonuclear reactions could be expected. Temperatures of between 2



THIS IS ZETA The heavy currents required are induced in the gas by means of a huge iron-cored pulse transformer which surrounds the doughnut. It is pulsed every 10 seconds from a bank of capacitors and can produce 200,000 amperes in the gas. To make the gas conducting it is kept slightly ionized by a radio-frequency set (on top). Separate coils round the torus produce a moderate axial magnetic field in the gas and prevent plasma instability or wriggling. The immediate programme with ZETA is to check positively that the neutrons observed arise from true thermonuclear fusions—this is not absolutely certain yet. Afterwards the power input will be raised and it is hoped temperatures of 25 million degrees will be reached. This is far hotter than the centre of the sun

and 5 million degrees were registered for periods of 2 to 5 thousandths of a second and pulses of neutrons were observed which corresponded fairly closely to the predicted theoretical yield. This was repeated many thousands of times. However, the origin of these neutrons has not positively been established and further experiments are in progress to check this. It is highly likely that the great majority arise from genuine thermonuclear fusions but it is just possible that some do not.

Success, too, at AEI laboratories

Measurement of temperature is an interesting aspect of this work. Normal spectroscopic methods fail because at these temperatures the deuterium is completely ionized and does not emit a line spectrum. However, this may be got over in one method by introducing a small quantity of oxygen or nitrogen and studying the spectral lines from this, as it is not completely stripped of its electrons. Velocities are calculated using the Doppler broadening of the spectral lines.

Thermonuclear research at AEI, Aldermaston, has been going on since 1951 when, owing to a government decision to classify this work, Sir George Thomson's team was moved there from Imperial College, London. Close collaboration has been maintained between the two groups and the line of approach has been largely similar—i.e. the pinched toroidal discharge. The AEI group has worked under contract to the Atomic Energy Authority but the firm has also invested a considerable sum of money themselves in the project.

After a lot of work on glass tori, the AEI workers have now produced a metal apparatus very similar to ZETA, but smaller, and known as SCEPTRE III. Their aluminium doughnut is in 12-in. dia tubing formed into a ring of 45 in. mean dia. The circular iron core weighs 4 tons and the primary winding is supplied from a capacitor bank similar to that used with ZETA. It can produce a plasma current of 200,000 amps by discharging 40,000 joules. Using SCEPTRE III, AEI reached temperatures of nearly 4 million degrees early in January 1958 and have detected neutrons in the same way as the Harwell team. So far, however, the same doubt as to their origin remains.

First objective attained

Development of thermonuclear work in four stages was foreseen by Sir John Cockcroft, Director of AERE, Harwell, in a statement.

1. The objective set for Thonemann's team was to produce temperatures of about 5 million degrees for a sufficient time for fusion reactions to be produced in deuterium gas at low pressure. During the course of this a series of tori of increasing size, culminating in ZETA, have been built. This objective has now been achieved and Sir John considered that to have achieved temperatures a third of those at the centre of the sun and to hold them for so long is a remarkable scientific achievement. However, the power produced in ZETA is only a million millionth of the input. The next move, but still in this stage, is to provide more condensers for ZETA in order to increase the temperature still more. Sir John thought that within a year the Harwell team would attain 25 million degrees and then the number of neutrons emitted per pulse would be at least ten thousand times the present figure of one million.
2. Even with improvements to ZETA the power produced will only be a minute fraction of the energy input. In order to break even with the D-D reaction—and for economic reasons that is the most interesting one, although the much easier D-T reaction will break even at M40°C—it is necessary to produce temperatures of about 300-400 million degrees. This will mean a new apparatus and, while experiments continue with ZETA work will be proceeding on its successor with the aim at reaching the break-even point. Sir John said there would be many new problems in this: new methods may have to be used to heat the gas to still higher temperatures and new techniques will be needed to measure them. New and exotic materials, too, might have to be used.
3. Having achieved 2, now would be the time to build a practical prototype thermonuclear power station — a Calder Hall.
4. Finally, we could proceed to a commercial proposition.

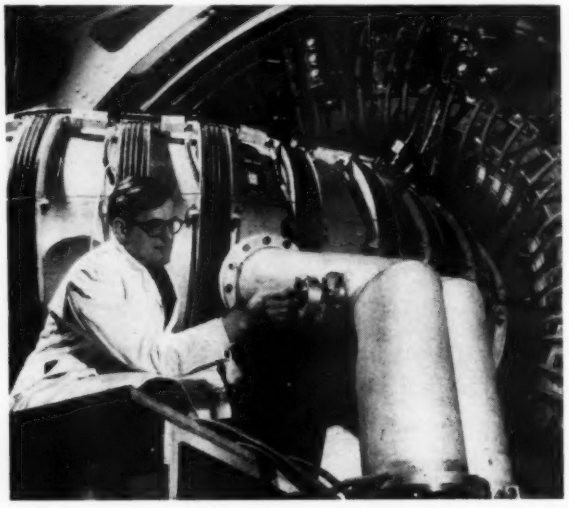
Sir John said it was difficult for us with our limited vision to see far enough ahead to say whether and when the final goal can be achieved but when pressed he put ten years as the minimum conceivable time for stage 4—but it could be fifty, he said.

Five groups working in US

Simultaneously with this information released at Harwell, Atomic Energy Commission chairman Lewis L. Strauss said certain areas of thermonuclear work must remain classified for the present. Mr Strauss said work began on a very small scale on thermonuclear research in the US in 1951 but today over 500 were working on the AEC's Sherwood programme. Work is located at five centres: Los Alamos, University of California Radiation Laboratory, Princeton University, Oak Ridge, and New York University. Mr Strauss said both countries had succeeded in producing and maintaining quite high temperatures in a plasma of light nuclei and containing it for brief but appreciable periods. However, he warned that in the field of fusion we were not yet at a point comparable to December 2, 1942, when the first self-sustaining fission reaction was obtained and that it would be a matter of many years before we would be able to build and operate commercial reactors utilizing the deuterium of the oceans. Nevertheless the present results were encouraging and the ultimate rewards so great that they justified the necessary expenditure of money, time and talent.

Of the work in the United States, it is possible only to indicate the line of approach. At Princeton, work is concentrated now on the 'Stellarator' project, the exact nature of which has not been disclosed. However, temperatures of M1·2°C were observed in 1956 in a race track tube of 4 in. bore. At Los Alamos the approach has been through a series of straight tubes—similar to the ones described by Kurchatov at Harwell in 1956 but with an axial stabilizing field. Using one of these 'Columbus' tubes, temperatures of M3° to M5°C have been observed with up to 10^8 neutrons per pulse. Los Alamos has also used glass tori—the 'Perhapsatrons.' One of these with a bore of only 2 in. was pulsed with 200,000 amps for 60 microseconds. Up to a million neutrons were recorded per pulse. This would correspond to a temperature of M6°C but it was not measured directly.

Thus although both British and US work is based on the principle of the pinched discharge stabilized by an axial



Close up of ZETA shows details of primary windings and axial stability coils. The tubes connect the space between the 1-in. thick doughnut and the relatively thin aluminium liners to the auxiliary vacuum system

field neither country has yet definitely proved genuine thermonuclear neutrons. In ZETA and SCEPTRE III, however, Britain has two machines which seem to be far more advanced than anything in America. Furthermore, no direct measurement of temperature has yet been reported except in these two British machines.

The main contractors for ZETA *were* METROPOLITAN-VICKERS ELECTRICAL CO LTD, *who also collaborated in the design. Sub-contractors included:*

TELCON MAGNETIC CORES LTD: *Ring-type transformer cores.*
PERMALI LTD: *Insulating material for transformer.*
WM. BEARDMORE & CO LTD: *Heat treatment of cores.*
A. E. CAWKELL: *Special electronic equipment.*
EDISON SWAN ELECTRICAL CO LTD: *Electric cables.*
STANDARD TELEPHONES & CABLES LTD: *Rectifier equipment.*
BRITISH INSULATED CALLENDERS CABLES LTD: *Condensers.*
LEE & WILKES LTD: *Copper tubes.*
GEO. KING, LTD: *Cranes and hoists.*
DYNAMO & MOTOR REPAIRS LTD: *Motor-generator set.*
W. E. CHIVERS LTD: *Building work.*
BRITISH THOMSON-HOUSTON CO LTD: *Ignitron switches.*
RADYNE RADIO HEATERS LTD: *Radiofrequency equipment.*
MARTONAIR LTD: *Air cylinders.*
20TH CENTURY ELECTRONICS LTD: *Multi gun cathode ray tubes and neutron counters.*

Several phenomena occurring in liquid metal systems can be interpreted as mass transfer processes. Depending on the source of free energy change, these can be regarded as either (1) thermal gradient transfer, or (2) isothermal transfer. This article considers the former, including experimental studies, and the processes involved: solution and precipitation.

In a cold zone precipitated material assumes a dendritic form. Taken by the author, this micrograph shows part of an iron-bismuth system (× 35)

MASS TRANSFER IN LIQUID METAL SYSTEMS

1. Thermal Gradient Transfer

J. W. TAYLOR, PhD

Research Department, Babcock and Wilcox Ltd

MASS TRANSFER IN FLUIDS is a well known phenomenon in chemical engineering and metallurgical technology, the former including solvent extraction processes in liquids, the latter carbon deposition in CO/CO_2 mixtures. More recently, the processing of nuclear fuels has involved mass transfer processes such as aqueous/organic and liquid metal/fused salt extractions. It is now possible to interpret many aspects of the interaction of liquid metals and solids, previously classed as 'corrosion effects,' as mass transfer phenomena.

In common with all mass transfer processes, those in liquid metals have as their driving force a free energy decrease, and on the basis of the source of this free energy change it is possible to separate liquid metal transfer processes into :—

1. thermal gradient transfer, in which the free energy decrease is that accompanying the decrease in solubility with temperature of a solute in a liquid metal solvent
2. chemical gradient transfer, where the free energy decrease is that of a reaction of a solute in the liquid with a solid in contact with the solution.

The present article is concerned with thermal gradient transfer, the basic steps of which are shown in fig 1; a later article will consider the other type of transfer.

From fig 1 it may be seen that the steps involved in thermal gradient transfer are:—

a. solution and/or diffusion of the solute element(s) from solid(s) present in the liquid metal at the hot-limb temperature T_H
b. transfer of the solution by thermal or forced convection from the hot limb to the cold limb
c. precipitation of the excess solute, corresponding to the solubility difference between temperatures T_H and T_C, at the cold-limb temperature T_C.

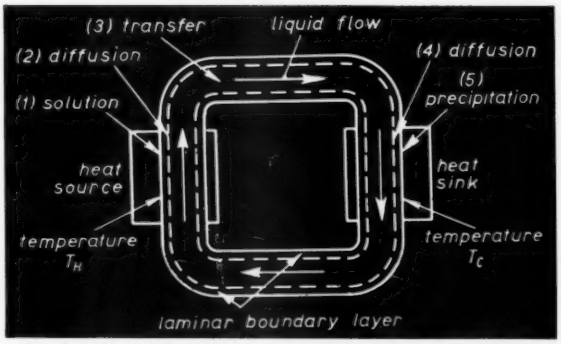


Fig 1 The elements of a thermal gradient mass transfer situation

Thus the essential conditions for this type of transfer are:—

1. a temperature differential in the liquid metal system

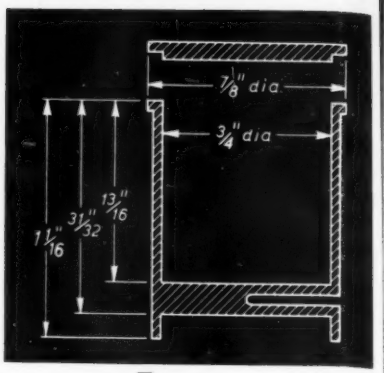


Fig 2 For tests in liquid bismuth a cylindrical can of the material to be tested is filled and the lid welded on

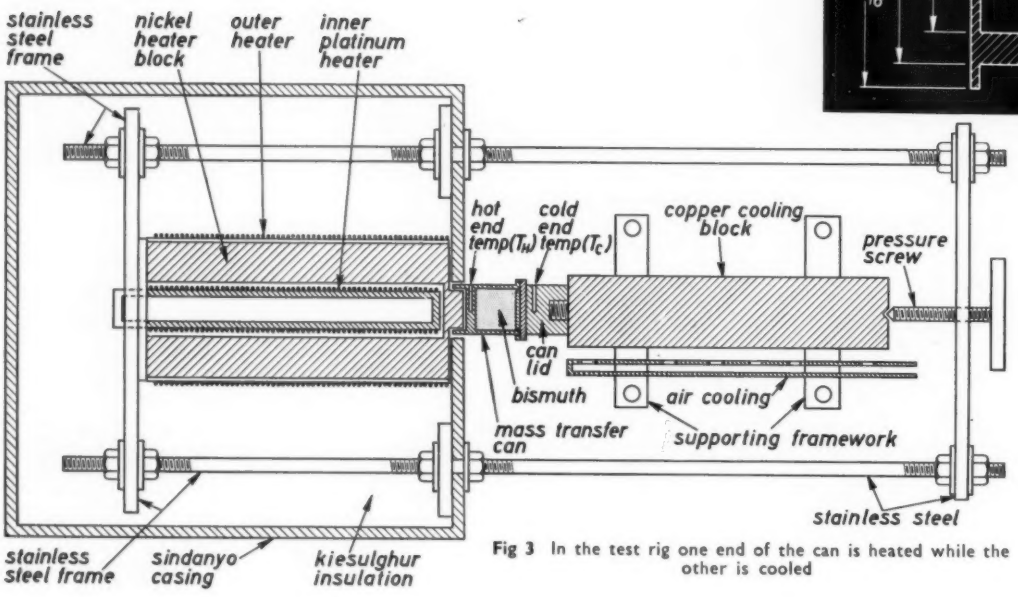
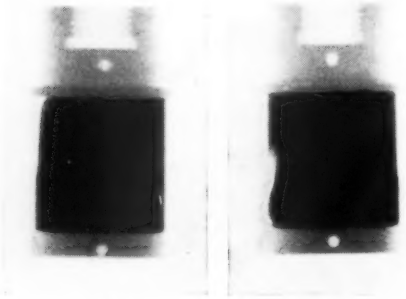


Fig 3 In the test rig one end of the can is heated while the other is cooled



(a) (b)

Fig 4 Radiograph during test shows conditions before and after 500 hours. (a) original can (b) after attack (actual size)

Fig 5 Metallographic examination (×2·8) shows effect of bismuth on a stainless steel can

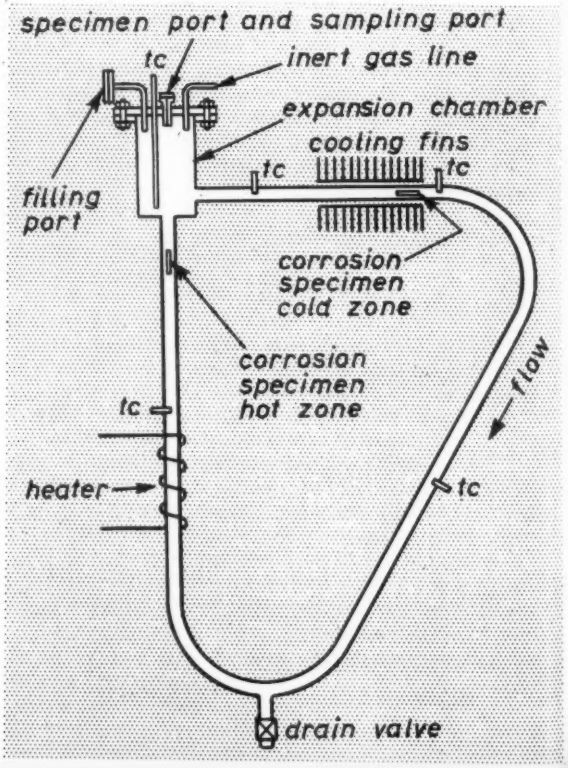


Fig 6 A thermal convection loop—a practical form of Fig 1 —is also used for mass transfer testing

2. a finite solubility, however small, of a solute (or solutes) in the liquid which decreases with decreasing temperature.

The nett effect of this metal transfer is either failure of the container at the hot-limb temperature due to solution attack or stoppage of the liquid metal flow due to precipitation at the cold limb.

EXPERIMENTAL INVESTIGATIONS

Methods of studying the complete process of thermal gradient transfer in liquid metals differ principally in the way in which transfer of the liquid from the hot to the cold limb is achieved, i.e. whether by natural thermal convection or by forced circulation. Pumped systems simulate most closely the conditions likely to be encountered in practice in a liquid metal cooling system, but operationally they are complex and frequently do not lend themselves to a study of a wide range of variables. Thermal convection tests are cheap to operate, are extremely useful for preliminary sorting-out tests, and serve a useful purpose in the study of the mass-transfer mechanisms; their one severe limitation is the relatively low velocities of liquid flow attainable.

Thermal convection methods

Can tests. This type of test has been used extensively by the author (*1*) in a laboratory-scale study of thermal gradient transfer in liquid bismuth.

The test is carried out in a cylindrical can of the material under investigation, in the form shown in fig 2. After filling the can with the liquid metal, the lid is welded on, giving a completely sealed system; any additions to the liquid metal can be conveniently made during this filling operation. The can is then assembled into the heat transfer system shown in fig 3 in which one end of the can, lying in a horizontal position, is heated to a temperature T_H from a nickel heater-block while the opposite end is maintained at a lower temperature T_C by means of the air-cooled copper cooling block.

Progress of mass transfer is followed during the test by radiography. Fig 4 (a) is a radiograph of a bismuth-filled, low-alloy steel can before test and fig 4 (b) the same can after 500 h with a temperature differential of 550 to 350°C; in the latter pronounced wall-thinning is apparent at the bottom left-hand corner. On completion of the test the extent and form of the transfer may be studied metallographically, fig 5; it is also possible to make this type of test semi-quantitative (*1*).

A modified form of this test, employed by Horsley and Alder (*2*), uses an electron beam, focused on the hot-end of the can, as the heat source. In this way very high heat transfer rates and thermal gradients can be established; operation of the assembly in vacuo permits readily oxidizable metals, e.g. molybdenum, niobium, tantalum, etc, to be assessed quickly and under rigorous conditions.

Loop tests. The essential features of this type of test have been referred to in fig 1 and more detailed experimental points are included in fig 6. Heating is usually effected electrically but oil-firing has been used on large-scale loops; cooling is normally natural or forced-convection air. The physical dimensions of loops which have been employed vary over a wide range from those of approximately eighteen inches perimeter used by Horsley (*3*) for in-pile testing to ones of up to a hundred feet for chemical engineering studies. Normally such loops have a perimeter length of a few feet.

In the larger loops facilities can be incorporated for introduction and removal of samples from hot and cold sections and for sampling of mass transfer materials in solution in the liquid metal. In this way the loop may be used for studying a series of specimens, but the presence of a second solute in the form of the loop material may complicate the mass transfer process. Smaller loops are constructed of the material under test and are normally destroyed during subsequent examination of the solution attack at the hot limb and deposition in the cold section.

The circulation velocity attainable in such loops is a few feet per second, determined principally by the temperature differential established from the hot to the cold limb and by the physical dimensions of the loop, e.g. the tube diameter etc; it is never greater than a few feet per second. Epstein (*4*) refers to the estimation of such velocities under ideal conditions, while Greenwood and Eaton (*5*) have recently considered a practical case in detail. These velocities are low compared to ones normally employed in liquid metal cooled systems, e.g. 10-12 ft/s, and constitute the one outstanding limitation of thermal convection loop tests. The latter, however, are cheap to operate and serve as a useful sorting-out process in liquid-metal studies before proceeding with the more elaborate dynamic tests detailed below.

Dynamic loop tests

In these the experimental conditions of temperature differential, liquid-metal purity and velocity simulate as closely as possible those existing in the full scale liquid-metal system. The essential difference between this type of test and that discussed above is that higher velocities, up to 20 ft/s, are obtainable from forced circulation by an

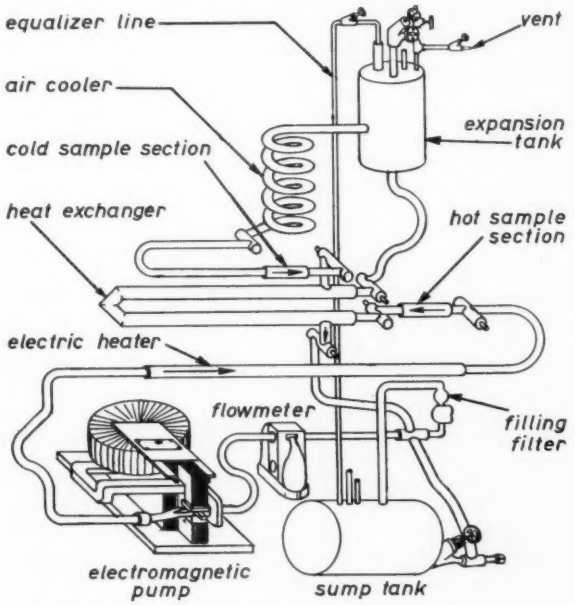


Fig 7 With a forced circulation system much higher flow velocities are obtained. Test specimens can be inserted in the pipes or can be actual parts of the circuit

electro-magnetic or mechanical pump. Due to the higher mass flow rates involved and to make the loop as versatile as possible, an elaborate heat exchange system has to be a feature of such dynamic loops with resulting complexity. The essential features of this type of test are shown diagrammatically in fig 7.

Test specimens in such loops may be in disc or strip form and introduced into the hot and cold limbs, but more frequently tubular forms are used which are welded into the rig prior to filling with liquid metal and are sub-

sequently cut out for metallographic study at the end of test.

Obviously such a loop system is the ultimate test of the mass transfer resistance of any structural material in a liquid metal under a specific set of conditions of temperature differential, velocity, and liquid metal purity, but much proving work can be carried out beforehand in the less elaborate tests described previously.

BASIC PROCESSES, VARIABLES

As outlined in fig 1, the two basic processes involved in thermal gradient transfer are:

a. dissolution at the hot limb
b. precipitation at the cold limb

and only when these two stages are understood in some detail will control of this liquid metal phenomenon become feasible in practice. A brief outline is now given of the known facts regarding these steps and of the variables that may influence them.

Dissolution process

Kinetic studies of the dissolution of solid in liquid metals have so far been aimed at determining which of two possible steps is rate controlling, these steps being:

a. the rate at which solute atoms pass from the solid lattice into the adjacent liquid layer
b. the rate at which solute atoms pass, by diffusion and/or convection, into the bulk of the liquid from a layer of saturated solution adjacent to the solid.

Such studies have been made in a number of different ways. The author has studied the rate at which a bath of liquid lead or bismuth came to equilibrium with solid copper under nominally static (*6*) and dynamic (*7*) conditions. The copper/lead and copper/bismuth systems resemble practical ones in that simple solution, i.e. no compound formation, is involved, but the solubilities are appreciably higher. Fig 8 shows typical concentration/time curves for the bismuth/copper system under nominally static conditions using a copper specimen 0·5 cm diam by

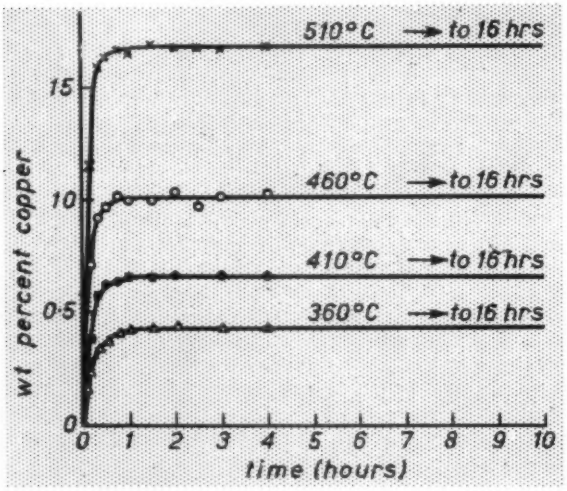


Fig 8 Solution-rate results for a copper-bismuth system under static test

3·0 cm long in a volume of 3·5 cc of liquid metal. Fig 9 compares static and dynamic conditions in the same system, the latter condition being achieved by a simple rotation of the solid at 1·6 cm/s. Table I gives an indication of the magnitude of the rates of solution involved in figs 8 and 9 during the initial stages when these were approximately linear. These figures illustrate in a general way the influence of temperature, equilibrium solute concentration, and velocity on the rate of solution. From a detailed consideration of these results (*6, 7, 8*) it was concluded that the effective rate-controlling step in dissolution in the systems studied was rate b. above. In the nominally static tests the rate of transfer of solute atoms to the bulk of the liquid was due to convection arising from density changes in the liquid during dissolution, while under dynamic conditions turbulent transfer took place.

TABLE I. Initial solution rates of Cu in Bi in static and dynamic conditions
(g/cm²/min)

temp (°C)	static	dynamic (1·6 cm/s)
360	$1{\cdot}17 \times 10^{-3}$	$9{\cdot}1 \times 10^{-3}$
410	$2{\cdot}66 \times 10^{-3}$	$16{\cdot}0 \times 10^{-3}$
460	$7{\cdot}04 \times 10^{-3}$	—
510	$11{\cdot}16 \times 10^{-3}$	—

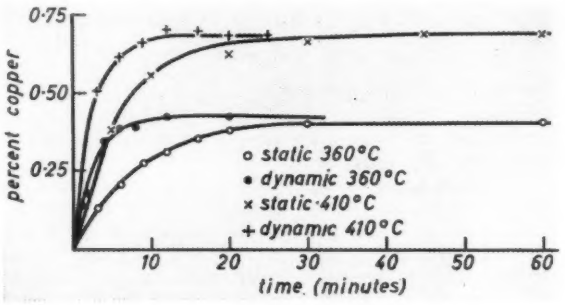


Fig 9 Solution-rate results for a copper-bismuth system for static and dynamic conditions

Bonilla (*9*) has studied the kinetics of the dissolution of solid in liquid metals from a chemical engineering point of view and has analysed the results in terms of dimensionless groupings, e.g. Reynolds, Schmidt, and Grashoff numbers, used extensively in the correlation of heat and mass transfer data in chemical engineering systems. Studies were made of the following three systems and geometries:—

1. the solution of zinc into mercury from the inside of a pipe under forced convection conditions at room temperature
2. the solution of lead spheres in a tightly packed bed into flowing mercury at room temperature
3. the solution of horizontal cylinders of zinc, tin, lead, and cadmium into mercury under natural convection conditions at room temperature.

In each case substantially good agreement was obtained between the solution-rate data for the liquid metal systems and correlations previously established for similar geometries with organic and aqueous systems in which the solution rate was known to be controlled by convective transfer of the solute. From this agreement it is inferred that the latter transfer rate is also controlling in the liquid-metal systems studied, a conclusion reached by the author (*6, 7,*) from independent study. More recently Bennett and Lewis (*10*) have carried out a series of experiments similar in principle to those of Bonilla (*9*) with essentially similar conclusions regarding the mechanism of solution.

Important factors. The processes referred to so far have been concerned with direct dissolution of a pure solute, but in practice there are two important factors which

must also be considered. Insoluble surface films, e.g. oxides, nitrides, carbides, etc, on the solute can prevent dissolution of the latter if the film is completely protective or can lead to very intensive localized solution (pitting) where flaws in this film exist. The danger of relying on such films stopping thermal gradient transfer in liquid metal systems need hardly be stressed; such films can only be considered of use if they are completely protective, completely self-healing, and mechanically stable under operating conditions. A second important consideration is that components may be leached preferentially from alloys by liquid metals even though the major alloying constituent is relatively insoluble. This leaching, although a slow process controlled by diffusion in the solid state, may seriously impair the mechanical properties or phase stability of the alloy.

Precipitation stage

The second important stage in the mass transfer process is that of precipitation of solute in the cold limb. Thus the solution of solute in liquid metal passes from the hot limb, more or less saturated, to the cooler one where it finally supersaturates, the excess solute separating there by a process of nucleation and growth. Unfortunately little is known about the kinetics of this separation stage since they are experimentally difficult to study. While it is almost certain that nucleation of the solute will be heterogeneous, i.e. occurring on small nuclei of insoluble components in the liquid metal or on the walls of the container tube, it is by no means clear how these nucleation centres compare in efficiency nor whether the subsequent rate of growth of these nuclei is sufficient to account for all the excess solute present in a given volume of liquid metal. Thus it may be that some of the excess solute over that corresponding to the solubility at the cold limb temperature may not precipitate, or, if it does precipitate in the bulk of the liquid, may be carried back into the hot limb where it redissolves preferentially.

Practically, the form of this cold zone precipitation has been well established in a number of studies (*5, 11, 12, 13*), in each case the precipitated material taking a characteristically dendritic form similar to that in the illustration at the beginning of this article; this radiograph shows a deposit obtained by the author (*1*) in a study of transfer of iron in bismuth. Also it is fairly well established that such deposits normally occur at the lowest temperature region of the loop system. Until recently, however, it was not clear what factors were responsible for the mechanical stability of such precipitates which were able to resist the momentum of liquid bismuth moving at velocities of the order of 250 cm/s. It now appears (*1*) that an essential and characteristic feature contributing to the stability of precipitates is the formation of a thin but regular layer of precipitate in intimate contact with, and strongly bonded to the tube-wall of the container at the zone of precipitation (fig 10). At an early stage in the precipitation process this uniform growth is replaced by the preferential growth of certain crystalline facets, either from thermal or concentration gradient considerations, with the final production of a dendritic form. The dendrites formed are however anchored securely to the boundary layer of deposit giving the latter considerable mechanical strength.

Effect of variables. For lack of experimental data it is not possible to specify in detail how the several parameters involved are likely to affect the precipitation. Increasing the temperature differential in the system will increase the degree of supersaturation when the solution from the hot limb enters the cold and the rate of nucleation and growth will almost certainly increase. Increasing velocity of flow of the liquid metal may have a variable effect. On the one hand the greater turbulence would be expected to reduce any supersaturation tendencies and would favour a rapid growth of nuclei, while on the other, the mechanical stability of the deposits may be insufficient at the very

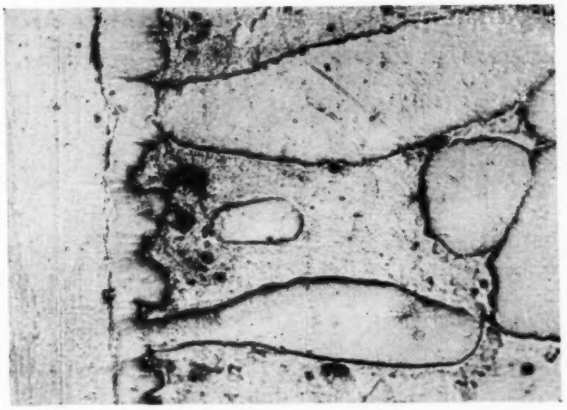


Fig 10 Micrograph of iron-bismuth system (× 175) demonstrates strong bonding at the wall

highest velocities, e.g. 750 cm/s, to give a stable plug. The form of the deposit, particularly as regards the relative abundance of the laminar or boundary precipitate and the dendritic one, may also alter with velocity. Non-metallic surface films may interfere with the adhesion of the laminar precipitate and hence modify the stability of the entire cold-limb deposit.

In conclusion, in liquid-metal systems having a temperature differential, thermal-gradient mass transfer of the container material may result in failure of the hot-limb component or stoppage of the flow due to precipitation in the cold limb. Experimentally this type of transfer may be studied in thermal or forced convection conditions; the former are simple and cheap to operate but the latter reproduce practical conditions in some detail.

The basic steps of the transfer process are: solution of container components at the hot limb, and precipitation of these at the cold limb. Several independent studies have been made of the kinetics of the first process and of the parameters which influence it. From these it appears that it may be possible ultimately to predict rates of solution in liquid metal systems on the basis of certain correlations established in heat transfer and mass transfer studies, the latter being made with aqueous and organic solvents. Much less is known about the kinetics of the second process but some information is available on the factors responsible for the mechanical stability of deposits and on where these deposits are most likely to occur.

Dr Taylor's second article, on isothermal transfer, will be published in next month's issue of NUCLEAR POWER.

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The world's first full-scale nuclear power station contains 1146 tons of graphite in each of its two reactors. Arranging the 13000 blocks to take account of thermal expansion, Wigner growth and neutron leakage combined to pose a formidable design problem.

THE CALDER HALL GRAPHITE STRUCTURE

E. LONG, AMIMechE

Deputy Chief Engineer, Civil Reactors, UKAEA Industrial Group HQ, Risley

THE DESIGN OF THE GRAPHITE structure for the Calder Hall reactors presented several novel engineering problems. The structure had to remain stable, accurate in dimension and position within the pressure vessel under all operating conditions. No maintenance would be possible during the life of the reactor. The main disturbing forces are variations in pressure and temperature, and irradiation effects.

The structure is built from approximately sixty thousand graphite components, which, when assembled, form a regular polygonal prism with its axis vertical. In plan it is a regular 24-sided polygon, 36 ft across corners and 27 ft high (fig 1). The fuel elements are placed in 1696 vertical coolant channels spaced on a square of 8 in. pitch. They are contained within the moderator proper which can be considered as a cylinder, 31 ft in diameter and 21 ft high, forming the central core of the graphite structure, surrounded on all sides by a reflector approximately 2 ft 6 in. thick. Vertical channels are provided for the insertion of control rods. The pressure vessel and the graphite structure were arranged with their axes vertical to ease the problems of supporting the graphite structure within the pressure vessel without subjecting the vessel proper to any large forces.

Square section chosen

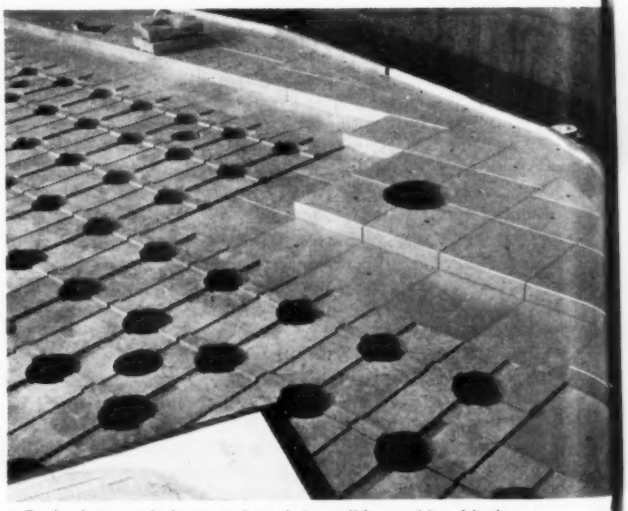
The components of the structure were machined from raw graphite blocks approximately 8·75 in. square and 32 in. long. The square section was chosen so that each coolant channel was contained in one column of bricks; the length was about the greatest at which it was convenient to manufacture the high purity bricks.

Because of their high capture cross-sections most general engineering materials were unacceptable as structural materials within the reactor core. The most satisfactory material when all factors had been considered proved to be graphite itself and after a preliminary examination of possible alternatives, all the structures finally considered were exclusively of graphite.

As a structural material graphite is quite suitable when used in compression so long as the section of the members is reasonably robust. However, when used in tension it is both weak and unpredictable, and all proposed structures which used graphite in tension were discarded.

Wigner growth

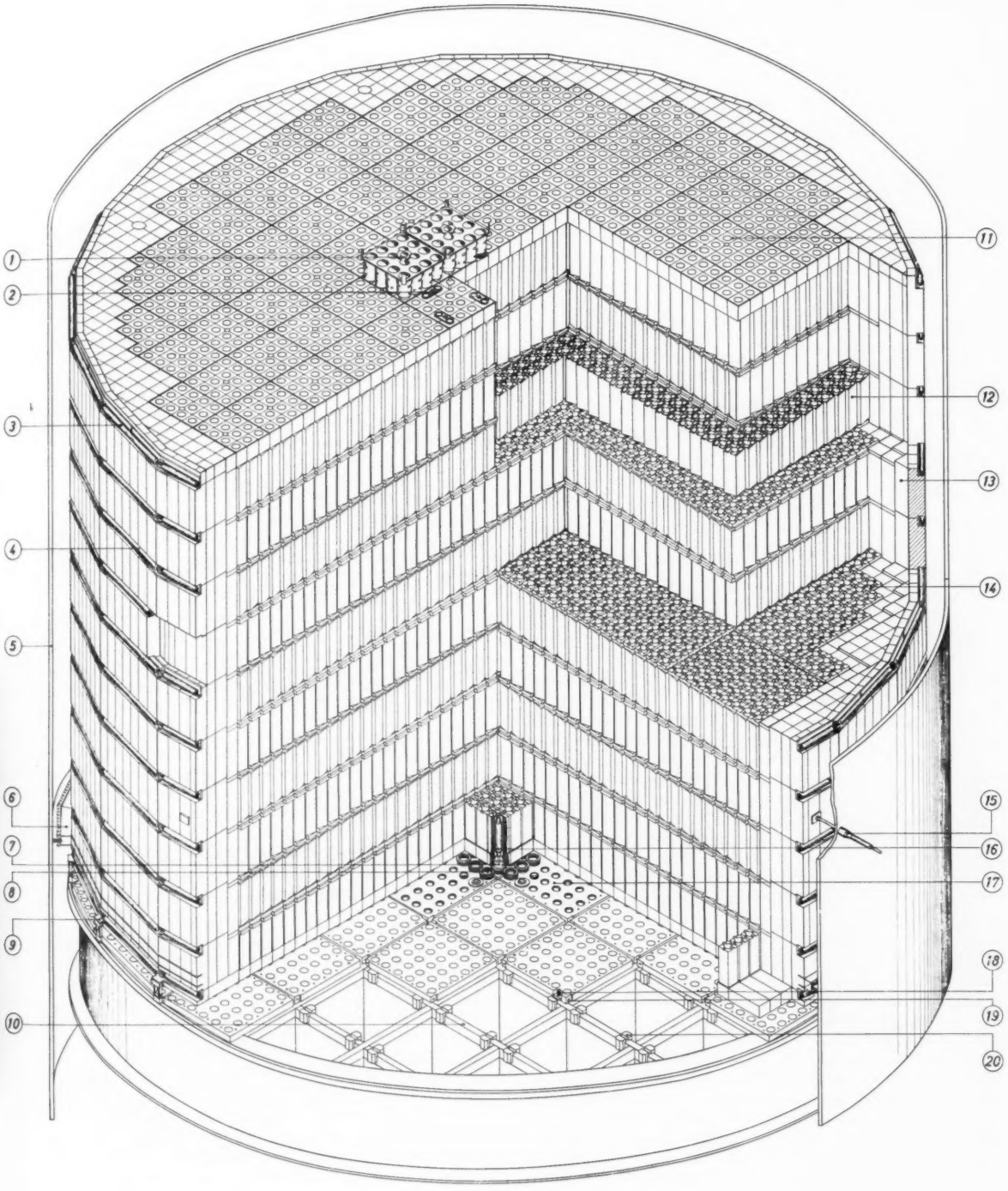
One of the most important factors influencing the design of graphite moderators is the phenomenon of growth under irradiation, generally referred to as Wigner growth. This growth, depends upon four factors: the quality or type of graphite, the direction of the grain of the graphite component, the neutron dose to which the graphite is subjected and the temperature at which the component is operating.



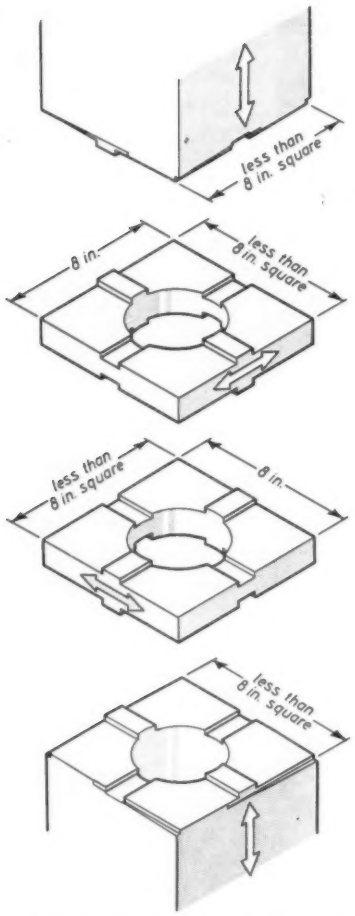
Fuel element holes are bored in solid graphite blocks to eliminate leakage of gas; control rod holes are formed by quadrant fillets at the corners of blocks. The side reflector portions of the core have no Wigner gaps and are of lower grade graphite

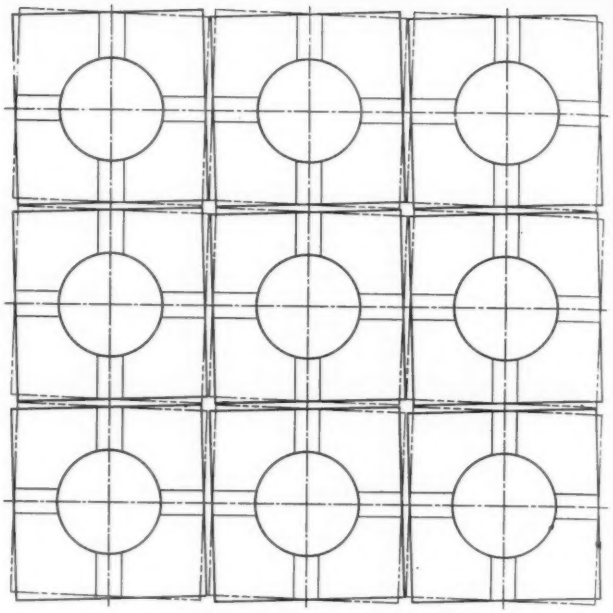
The quality is chosen from consideration of its nuclear properties: high density, i.e. high scattering cross-section, and low capture cross-section. The grain is determined by the manufacturing process and is along the length of the

How it is done . . .



. . . the first complete view published. **Fig 1** shows: (1) Charge pan; (2) Charge pan supports; (3) Top side restraint; (4) Intermediate side restraint; (5) Pressure vessel; (6) Gas seal; (7) Fuel element support boss; (8) Graphite support bearing; (9) Bottom side restraint and radial keys; (10) Grid; (11) Charge group; (12) Moderator bricks; (13) Reflector bricks; (14) Moderator tiles; (15) Graphite measuring (Wigner) probe; (16) Fuel element support strut; (17) Base support plates; (18) Levelling screws; (19) Support plate positioning screw; (20) Levelling pads





PLAN SHOWING BRICKS TWISTED THROUGH 2° TO REDUCE NEUTRON STREAMING

Fig 2 Between each pair of vertical core blocks are laid a pair of interlocking graphite tiles with their minimum Wigner growth directions (arrowed) at right angles. Note how the keys and keyways are at 2 degrees to the side of the blocks, also the grooves at the top edges of the blocks to give clearance for the tiles on the adjacent columns

brick parallel to the direction of extrusion. It will be found, particularly in the qualities where the orientation of the grain is most pronounced, that the rate of growth measured along the grain is considerably less than that measured perpendicular to the grain. The ratio of transverse to axial growth rates varies from unity when there is no orientation of grain, to a hypothetical infinity when highly oriented graphite is used in regions of high temperature where the axial grain rate becomes insignificant.

Once the quality had been chosen, the two remaining factors which influence growth are flux and temperature and their influence is in a sense in opposition to each other. It can be generally stated that the higher the neutron flux level the greater the growth rate will be and conversely the higher the temperature the lower the growth rate. Therefore, as the flux varies across a diameter as a Bessel function and vertically as a cosine function, the maximum growth would be expected at the centre of the core if flux were the only variable affecting growth. However, as the temperature increases from the bottom to the top of the structure, this has the effect of lowering the position of maximum growth until it is only a few feet above the bottom of the core proper.

Wigner growth is one of the most important factors influencing the design of graphite moderators, and its effect of distorting the structure must be kept within acceptable limits.

Alternative structure types

Consideration was first given to the practicability of a completely solid structure with all bricks touching each other. However, the distortions of the structure caused by Wigner growth during the life of the structure would have had such deleterious effects that such a solution had to be rejected. The three main difficulties which would have been encountered are:—

1. the greatly increased interchannel and out-of-channel coolant leakage due to the tilting of the bricks; this would have resulted in degradation of the reactor heat output with its consequent limitations of pile power
2. the difficulty of inserting and adjusting the control rods
3. refuelling operations would have been prejudiced.

In addition the general stability of the structure would have been suspect. All the structures considered achieved their reduction in diametrical growth by separating the bricks with a small space around the four vertical sides of each individual brick, so that when growth occurred the bricks would tend to fill up these interstices and therefore growth would have little or no effect is displacing the coolant channels.

It was evident that a structure composed of separate columns of bricks 8 in. square and 27 ft high without any lateral support would have been most unstable and methods had to be considered to support the separate columns. All the methods investigated to overcome this instability had one common feature: they sought to pin the separate columns to those adjacent by spacers of graphite with the grain so arranged that when growth occurred in these spacers it would be at the axial rate, which, as previously noted, is much lower than the transverse rate. This can perhaps be more clearly conceived if the structure is considered as separate columns of graphite pinned in space by ties of graphite of which the grain is

so arranged that the pile grows in all directions at the lower axial rate.

In this conception of using the graphite itself in such a way as to cause growth only at the reduced axial rate lay the key to the design of an acceptable structure.

Coolant channels through vertical axis

It would have been possible to provide coolant channels by machining quadrant fillets on the four long edges of the brick, or by machining two semi-circular grooves in the middle of the opposite side. However, all structures using such forms of coolant channel suffered seriously from interchannel leakage and from the fragility of their components. It was decided therefore to have the coolant channel bored through the vertical axis of the brick.

The structure is made up of bricks and tiles as shown in figs 1 and 2, the section of the brick being somewhat less than 8 in. square depending upon the Wigner gap. The tiles are rectangular in plan section, 8 in. long and less than 8 in. wide, again depending upon the Wigner gap. Layers of bricks with their axes vertical are each interleaved with two horizontal layers of tiles. All the tiles in the lower layer are arranged with their long sides running north to south, forming parallel separated chords across the pile face, and those in the upper layer with their long sides east to west. Elastic garters are placed around the outside of the tile layers, thus holding the bricks in their correct lattice position with a gap around their four vertical sides. With this arrangement displacement of the channels during irradiation will be at the much lower axial growth rate. Cruciform features were chosen to locate the tiles and bricks relative to each other in preference to circular spigots: not only do they prevent relative rotation of the different components, they also require less clearance in the registers to accommodate the differential growth of mating parts.

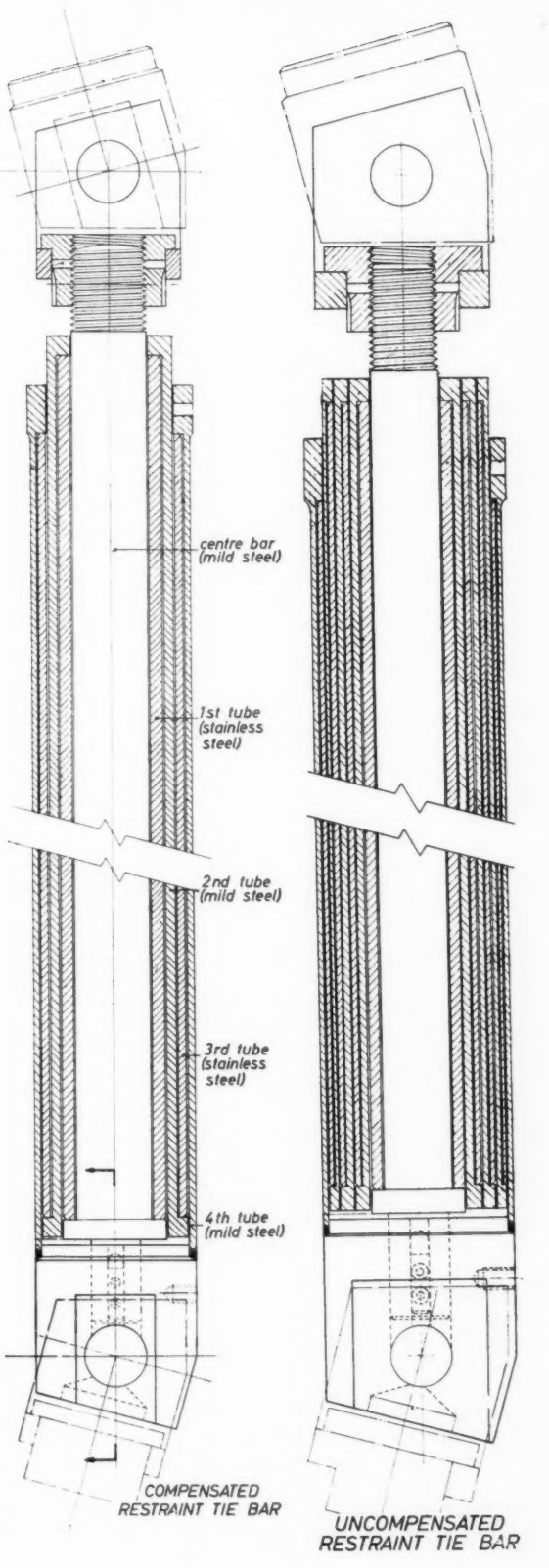
This design gives a stable structure in which the channels are appropriately spaced, and under irradiation grows sensibly in all directions at the lower axial grain rate. The tiles represent a small portion of transverse growth in the vertical direction.

Control rod holes were provided by machining quadrant fillets from the corners of the four bricks which immediately surround the control position. A control position was provided for every charge group, comprising 16 coolant channels. The peripheral reflector was built solid, i.e. without Wigner gaps, as growth in this region will be very small. Small gaps were provided in the inner portions of the top and bottom reflectors, where growth, although small, is not negligible. As the side reflector is solid there was no need for tiles.

High density graphite needed

At the periphery of the bottom reflector the bricks were laid horizontally to provide a supporting mat for the trapezoidal and triangular shaped bricks immediately above. Due to the difficulty of containing the non-rectangular reflector bricks, the outer reflector bricks were made 8 in. square and formed a skin inside which these odd sectioned bricks were contained.

It is necessary for the moderator material to have a high scattering cross-section, which requires a tightly packed molecular structure. Thus it is necessary for the graphite


centre bar (mild steel)
1st tube (stainless steel)
2nd tube (mild steel)
3rd tube (stainless steel)
4th tube (mild steel)
COMPENSATED RESTRAINT TIE BAR
UNCOMPENSATED RESTRAINT TIE BAR

Figs 3, 4 Calder's 24-sided graphite core is held in place by rings of pin-jointed tie rods of compound construction known as garters. Top and bottom garters (left) are of compensated construction to give an overall thermal expansion coefficient the same as graphite. Intermediate garters (right)—entirely in mild steel—are not compensated but allow for Wigner growth which can exceed thermal expansion

to be not only extremely pure to reduce parasitic capture but also to have the minimum of porosity to ensure that the mean free path of the neutrons in the core is a minimum. This involves expensive processes in the production of graphite of appropriate qualities. It was decided to use graphite of a lower quality in the reflector to reduce costs. In the reflector the neutron flux is low and therefore little neutron loss is caused by using this poorer graphite.

In addition to using very dense graphite, it is also necessary to ensure that there is a minimum void space in the graphite structure. Some voidage is inevitable because of coolant channels, Wigner gaps, etc; however, this had to be kept to a minimum.

The diameters of the coolant channels were fixed largely by heat transfer considerations. Three different diameters were chosen, their size increasing towards the centre of the moderator, the region of maxium heat release. It would have caused less voidage if a larger number of channel sizes had been chosen, but it simplifies the fuel element charging arrangements to have only one channel size in each charging group of 16 channels fed from one charge position. Only one type of fuel element is then required when charging any particular group.

As flux and temperature vary throughout the reactor, the rate of Wigner growth varies both radially and axially. Maximum density is obtained if the gap between bricks is reduced the further they are from the point of maximum growth. As there are over 13,000 bricks in the moderator, this would have required an unacceptable number of different types and a compromise was made between voidage and variety of brick types by having four sizes of gaps in the moderator and no gap in the reflector.

Prevention of neutron streaming

Long free paths in the Wigner gaps through the moderator would permit a portion of the neutrons to escape from the higher flux regions to those of lower flux and so into the reflector, where the probability of their being lost to the system is increased. To reduce this effect, bricks in the moderator are rotated 2° about their vertical axes relative to the pile matrix, each layer being turned in a direction opposite to those immediately above and below it.

As can be seen from fig 2, rotating the bricks allows a free path for neutrons of only 8 in. in a horizontal plane. By rotating the bricks in opposite directions from layer to layer, the free area for vertical streaming has been reduced by half, in addition to which there are the tile layers to reduce further this streaming effect. With this form of rotation, the same brick types can be used in every layer. It is necessary merely to turn a brick upside down for it to be suitable for layers immediately above and below, i.e. rotated in the opposite direction.

Twisting the bricks has necessitated small undercuts along the top and bottom edges of the bricks to avoid their fouling the tiles on adjacent bricks. Such fouling could occur as a result of different growths in adjacent columns or of the accumulation of machining tolerances.

Side restraint provided

Compensated restraints surround the top and bottom graphite layers. Each garter comprises 24 members, one for each side of the structure, which are pin jointed at their extremities to those adjacent, thus providing a continuous horizontal band around the graphite. Each member comprises four tubes and a central rod, as shown in fig 3. The rod, the second tube and the outer tube are mild steel; the other two are stainless. At its ends each member bears on the ones immediately inside and outside of it in such a way that the expansion of the three mild steel members is counteracted by the expansion of the two stainless steel ones, in the same way as a compensated pendulum. Thus the effective thermal expansion of the whole member between the pin joints can be made substantially the same as that of graphite.

The intermediate restraints (fig. 4) are of much the same form as those at the top and bottom but are not compensated, being composed solely of mild steel members. There are 9 links in place of 5, and they are smaller in cross-section. This allows for the extension required because of Wigner growth, which may be greater than that caused by temperature changes alone.

The strain to which each individual tube or rod is subjected will be only one ninth of that which the complete member has to accommodate and also, as they are smaller in cross-section, the centripetal reaction which the member exerts upon the structure will be smaller. This is necessary as the tiles are small in section relative to the top and bottom reflector bricks. The centripetal reactions of all the restraints are transmitted through the pin joints to the angle brackets which have a large surface area in contact with the graphite. Conventional coil springs would not have given a satisfactory solution because of the difficulty of providing the required force and rate within the small space available.

Grid support at bottom

The graphite structure is supported by a grid at the lower end of the vessel. The grid rests upon 20 knees transferring the weight of the structure through the vessel wall to the 10 inverted 'A' frames which stand on the concrete raft, thus subjecting the pressure skin to a minimum load. If the graphite structure had been placed directly on the steel plates which rests on top of this grid, it would have opened up due to the much greater thermal expansion of steel relative to graphite. This differential expansion over the diameter of the structure could be as much as $1\frac{1}{2}$ in. under certain operating conditions.

Although in general engineering practice flaked graphite is often used as a lubricant, the graphite used in the structure has a relatively high coefficient of friction when in

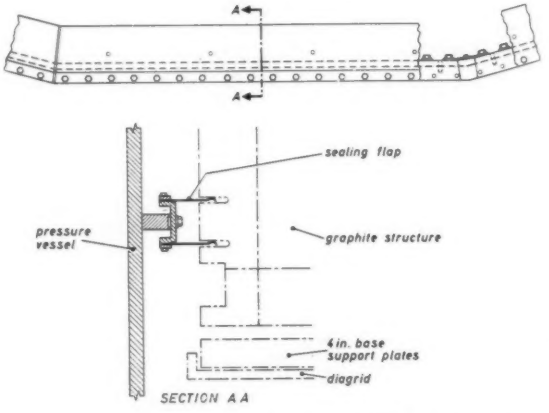


Fig 5 To prevent coolant gas from bypassing the core, a sealing device is fitted all the way round near the bottom. This is in the form of a metal diaphragm fixed to the pressure shell and slotting into the graphite. Two are fitted to improve effectiveness and insure against failure of one

contact with metallic surfaces, particularly when this occurs in a dry CO_2 atmosphere. If no attempt had been made to reduce this frictional force, it would have required either a centripetal restraining force in excess of 3 tons per foot of periphery or a garter, similar to the side restraints already described, capable of withstanding a tensile load in excess of 50 tons with a minimum extension.

To avoid the use of massive components, rolling was substituted for sliding friction to reduce these very large forces. The solution adopted uses ball bearings having flat tracks, one bearing being provided for every column of bricks with a coolant channel and others evenly spaced over the reflector area. The bottom races of the bearing rest on 4 in. thick steel plates, having holes at the lattice pitch for entry of the coolant gas to the fuel element channels.

Gas seal necessary

The bottom 24 brackets transferring the restraining force to the graphite are provided with U-shaped lugs having adjusting screws. These screws serve the function of keyways which engage with 24 keys welded to the outer edge of the top peripheral flange of the grid. Thus relative expansion between the graphite structure and the support plates is allowed while maintaining the graphite structure in its correct position in the pressure vessel.

The vessel has an inside diameter of 37 ft, leaving an annular gap between it and the graphite structure varying in width from 6 to 8 in. It was not possible to build the graphite structure touching the vessel wall because of the need to accommodate Wigner and temperature expansion. As this gap allows coolant to by-pass the fuel element channels, a seal was necessary to prevent degradation of the heat output. This is in the form of two horizontal metal diaphragms (fig 5) rigidly attached to an internal flange on the vessel and sliding in a peripheral slot in the graphite structure. A double seal serves both to reduce leakage and to provide insurance against the most unlikely failure of either. Each diaphragm is composed of 24 plates, one for each side of the structure. When assembled, end clearance between adjoining plates is adjusted by moving the plates radially.

Spider support for fuel elements

The fuel elements are stacked vertically one above another in the coolant channels. They are held coaxial with the channel by a three armed spider attached to the upper end of each element and by a male cone at the lower end of one element engaging a female cone provided at the top end of the element immediately below. The complete column of elements is supported by a strut shown in fig 6. This strut transmits the weight of the column of fuel elements to the support boss at the bottom of the channel and hence through the bearing to the main support plates.

Although great care has been taken to avoid the inadvertent dropping of a fuel element, it was considered advisable to incorporate a device to reduce the impact force of the element on the strut or upon elements supported by the strut. To obtain this cushioning effect a broach has been attached to the lower end of the strut. If the strut is struck a heavy blow, the pin is first sheared and then the cutting tool broaches metal from the inside surface of the tube—the broach has a stroke of 3 in.

There are three sizes of coolant channel in the moderator, the largest being in the central zone and the smallest in the outer zone, thus providing a coarse form of coolant metering. More accurate metering was achieved by gags incorporated in the lower end of the fuel element support strut, these gags forming an annular orifice in coniunction with the turned bore of the fuel element support boss.

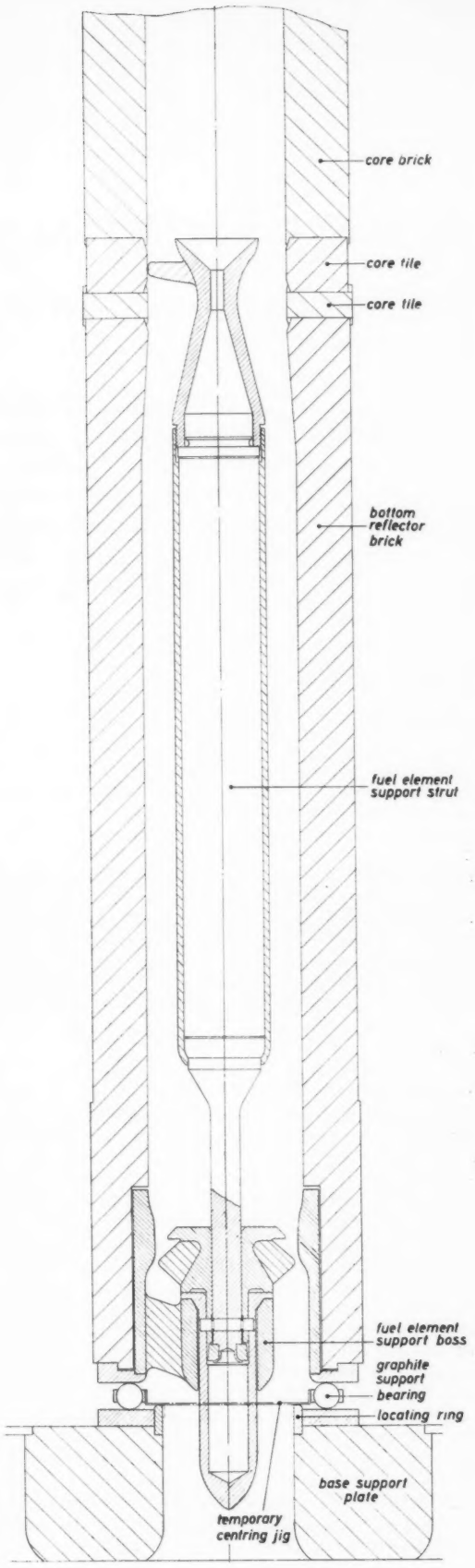


Fig 6 The whole weight of the column of six fuel elements is supported by a strut held in a three-legged fitting at the coolant channel entry. It incorporates a shear pin and broach device to minimize damage if an element is accidentally dropped. Note gag unit to adjust gas flow through channel and ball-bearing support for each assembly

NUCLEAR HEAT

a symposium on utilization prospects

In 1957 about 223 million tons of coal were produced in Britain but only about 20 per cent of this was used by the electricity authorities. Nuclear heat could, if available in quantity at an economic price, replace much of the coal that is at present used in industry. Last year a conference was held at Harwell to go into ways and means, and its proceedings were recently declassified. Here are some highlights as put forward by speakers at the meeting.

A Harwell viewpoint

C. M. NICHOLLS
AERE Harwell

The cost of heat from nuclear reactors is very dependent on the capital cost of the equipment and on the fuel inventory charges. Estimated trends in the variation of the capital cost of reactors emphasize its large dependence on size. Consequently, heat will be expensive if produced from small reactors. If reactors are made sufficiently large, the contribution of capital cost to final cost of heat can become quite low. In all reactors the fuel cost is expected to be small, particularly for those with a high conversion factor and long fuel life in the reactor. Thus large nuclear reactors can be regarded as a source of cheap heat. The larger the scale of application the more likely is the nuclear power station to be the most economic method for heat production.

Electricity convenient but wasteful

The distribution of energy as electricity has the valuable feature of almost universal adaptability. The electricity can be efficiently re-converted into heat in small or large amounts, at high or low temperatures as the user requires. However, the efficiency with which heat can be converted to electricity is moderate and the electricity has to be used as it is produced since no reasonable methods of large scale storage have been evolved. Schemes which utilize the heat that would otherwise be wasted in electricity production have often been proposed. There is no reason why such schemes should not be carried out with nuclear fuel, but the limited scale of application of these methods at present would rule them out on the grounds of capital expenditure for the nuclear power station.

In general, at the point of use, heat is required in comparatively small amounts. The problem becomes one of the distribution and storage of heat. This can be done as follows:—

1. The heat can be transported from the reactor to the point of use e.g., as a hot liquid or gas. The range of transport is necessarily quite limited.
2. Provided the temperature is high enough, the heat can be used to convert appropriate raw materials into gases which can be distributed over long distances and easily stored.
3. The heat can be used to produce liquid fuels.

Steam production

Reactor heat must be transported to the point of industrial application in a form that will enable it to be efficiently utilized. Process gases can be heated directly in the reactor or by means of heat exchangers in secondary circuits, but the use of process solids will probably require fluidized or slurry techniques.

Steam is one of the first materials usually considered for the transport and use of heat. It is also a process chemical in its own right and, if the scale of use were sufficiently large, nuclear power could be an economic source of this material. A survey by the Ministry of Fuel & Power showed that the chemical industry was the largest user of steam and the whole of that industry used just over 14 million lb/hr. This could be produced by ten 500-1000 tMW reactors. It was produced in 300 different establishments, giving an average range of 3-10 megawatts per establishment with the biggest about 40 megawatts; nuclear boilers would be very costly in the average range.

Scope for VHT reactor

All gases likely to be produced as fuels will also be of interest as chemicals. Since a large scale of operations is postulated, raw materials should be cheap and readily available. This means water, air and coal with oil, coke and other carbonaceous materials of secondary, but still major, interest.

The gases of particular interest are hydrogen, carbon monoxide and methane which, in addition to their use as fuels, comprise the basic materials of the large scale synthetic chemical industry. Table I lists a selection of reactions to produce these gases together with the temperature ranges of interest.

The high-temperature gas-cooled reactor is the most

Main product		Reaction equation	Temperature at which Kp = 1 °C	Temperature range of interest °C	Heat of reaction ΔH kcal 1500°K	Remarks
Hydrogen	1	$H_2O+CO \rightarrow CO_2+H_2$	800	←200 – 650	— 7·2	Catalytic, reverse of (9)
	2	$2H_2O+CH_4 \rightarrow CO_2+4H_2$	590	630 – 830→	+ 47·1	Reverse of (13)
	3	$C_nH_m \rightarrow H_2+C_nH_{m-2}$	—	1000 (500)→	—	Lower temp. is for catalytic Platforming
Hydrogen and Carbon Monoxide	4	$C+H_2O \rightarrow CO+H_2$	670	730 – 1030→	+ 32·3	
	5	$CH_4+H_2O \rightarrow CO+3H_2$	610	660 – 780→	+ 54·3	Reverse of (12)
	6	$CH_4+CO_2 \rightarrow 2CO+2H_2$	630	670 – 780→	+ 61·5	Reverse of (11)
Carbon Monoxide	7	$C+CO_2 \rightarrow 2CO$	700	750 – 960→	+ 39·5	
	8	$2C+O_2 \rightarrow 2CO$	—	—	— 55·1	Incomplete combustion of carbon
	9	$H_2+CO_2 \rightarrow CO+H_2O$	800	930→	+ 7·2	Reverse of (1)
Methane	10	$C+2H_2 \rightarrow CH_4$	560	←330 – 480	— 22·1	Catalytic
	11	$2CO+2H_2 \rightarrow CH_4+CO_2$	630	←530 – 610	— 61·5	,, , reverse of (6)
	12	$CO+3H_2 \rightarrow CH_4+H_2O$	610	←480 – 590	— 54·3	,, , reverse of (5)
	13	$CO_2+4H_2 \rightarrow CH_4+2H_2O$	590	←460 – 560	— 47·1	,, , reverse of (2)
Steam-iron reactions	14	$Fe+H_2O \rightarrow FeO+H_2$	1600	Too high	— 1·6	
	15	$Fe+CO_2 \rightarrow FeO+CO$	(530)	—	+ 1·9	
	16	$3FeO+H_2O \rightarrow Fe_3O_4+H_2$	680	830 – 930→	— 6·9	
	17	$3FeO+CO_2 \rightarrow Fe_3O_4+CO$	550	850→	— 3·3	
Decomposi-tions	18	$2H_2O \rightarrow 2H_2+O_2$	5000	—	+119·6	
	19	$2CO_2 \rightarrow 2CO+O_2$	3000	—	+134·0	

TABLE I Some selected reactions for the production of gases

promising for these applications although it would be desirable to increase the temperature above that at present considered. While the temperature that can be achieved will affect the choice of reactions, the realization of higher temperatures than is required by reaction equilibrium and kinetic considerations would lead to the desirable possibility of using the waste heat after power production.

Closed cycle gas reactions

If heat alone could be used to carry out the desired reactions then the production of the gas, together with its final use could lead to closed cycle operations with savings in raw materials. This might be desirable if heat was sufficiently cheap. Such hypothetical closed cycles are illustrated in fig 1 in which heat is used to produce the desired gases: (a) hydrogen and (b) carbon monoxide. These gases are then reacted with Fe_2O_3 to produce a desired product iron, and reform the original material used for the production of the gases.

TABLE II Heat conditions in present or projected reactors

Reactor	Primary coolant temp. °C	Possible steam conditions temp °C	pressure psig
Improved Calder	390	370	770
Sodium-graphite	500	450	800
Homogeneous aqueous	300	220	350
Organic moderated	400	300	415
Liquid-metal-fuel	500	500	1250
Pressurized water	260	230	450
Boiling water	300	300	900
High temp. gas cooled	800	550	1500
Fast reactor	425	400	600

However, commonly occurring raw materials are in their most stable thermodynamic state and their dissociation requires the expenditure of considerable energy. The thermal dissociation of water and carbon-dioxide as shown above requires temperatures far in excess of those achievable in present or projected controlled fission reactors. These are given in Table II.

Hydrogen production

Water can be decomposed into hydrogen and oxygen by the action of radiation in, for example, the aqueous homogeneous reactor. Assuming that no steps were taken to inhibit the decomposition of the water and that such a reactor could be operated, the rate of hydrogen produced by radiation would be only about one hundredth of that which could be produced electrolytically by the same reactor even assuming only 20 pct efficiency of conversion of heat to electricity. This is an indication of the stability of naturally occurring materials and the inefficiency of fission irradiation in these reactors for decomposing water. It would be of more interest to find other reactions likely to be more efficiently carried out and of the design requirements of equipment for high efficiencies.

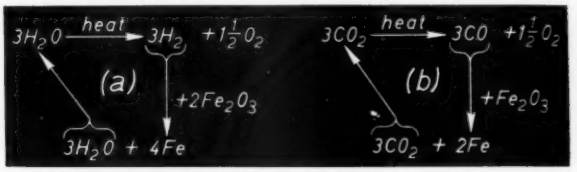


Fig 1 Possible gas production cycles

The steam-iron process (equation 16, Table I) requires the use of a reducing gas such as water gas (40 pct CO, 50 pct H_2) or producer gas (25 pct CO, 15 pct H_2) to regenerate the FeO from Fe_3O_4 and fairly high temperatures (800-950°C). The use of other metal oxides in which the required oxide could be regenerated by heat at a reasonable temperature, may lead to a process for hydrogen production not requiring the use of carbon.

Hydrogen Production Cycle: $XO_n + m\,H_2O \longrightarrow XO_{n+m} + m\,H_2$

Oxide Regeneration Cycle: $XO_{n+m} \xrightarrow{\text{heat}} XO_n + \frac{m}{2}O_2$

The utilization of carbon as a chemical can lead to carbon-monoxide and hydrogen by the well-known reactions given in equations 7, 1 and 4 (Table I).

$$C + CO_2 \xrightarrow{750\text{-}960^\circ C} 2CO - 39{\cdot}5 \text{ k cal.} \quad \ldots\ldots\ldots\ldots(7)$$

$$CO + H_2O \xrightarrow{200\text{-}650^\circ C} CO + H_2 + 7{\cdot}2 \text{ k cal.} \quad \ldots\ldots(1)$$

$$C + H_2O \xrightarrow{730\text{-}1030^\circ C} CO + H_2 - 32{\cdot}3 \text{ k cal.} \quad \ldots(4)$$

Reactions (7) and (1) might be combined as shown in Figure 2, assuming that the necessary temperatures could be achieved, that the reactor cooling could be balanced and a suitable source of carbon could be found. Coal and coke would be the first materials to consider even if they do bring complications due to the presence of ash and sulphur. The US Bureau of Mines has operated a pilot plant for oxygen gasification of coal in which the oxygen and steam were superheated to 540°C and then reacted with coal, the temperature reaching 1370°C in this chemical reactor. As a logical follow-up, the USAEC and the Bureau of Mines are investigating the possibilities of coal gasification using nuclear heat.

It is not intended to discuss the value as chemicals or fuels of these gases and other products such as methane that can be made from them, except to emphasize that an abundant, cheap supply can make very considerable contributions to the economics of a country. This is demonstrated by the importance of natural gas to the USA, Canada and, in recent years, to Italy. Perhaps this is a context in which the use of nuclear heat might be profitably considered—to supply to this country, on a national scale, a raw material and fuel not supplied by nature.

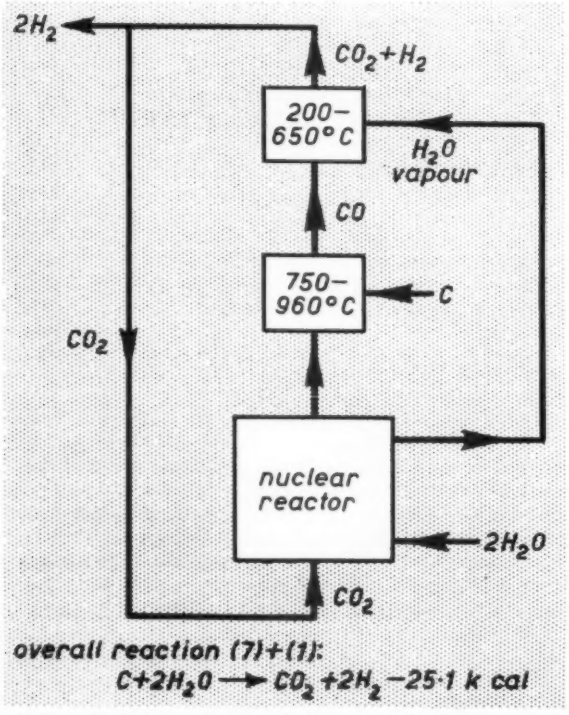


Fig 2 Production of hydrogen and synthesis gas from water and carbon

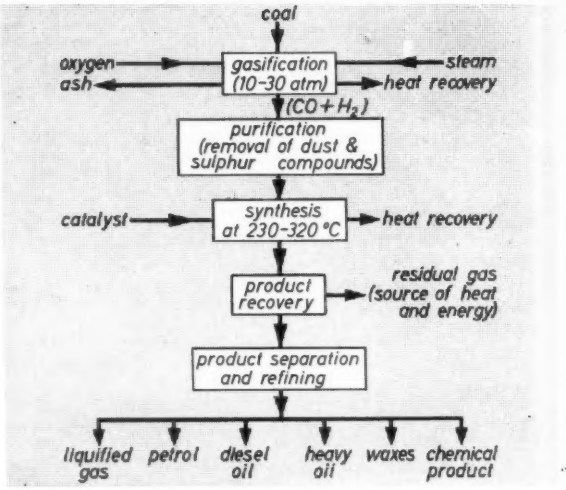


Fig 3 Main steps in Fischer-Tropsch synthesis of liquid fuels

A survey of the fuel requirements of any country demonstrates the complementary roles of electricity, gaseous and liquid fuels. This country has very limited or negligible indigenous supplies of liquid fuels so that importation or synthetic manufacture are necessary. An analysis of the heat requirements of the many processes that have been suggested and developed for the manufacture of synthetic liquid fuels would be useful in determining whether nuclear fields can make useful contributions to these processes. The initial steps in these processes are the same as those in the production of gaseous fuels (Figure 3). In fact, the cost of producing the purified, compressed synthesis gas can account for as much as 80 pct of the total production cost of Fischer-Tropsch type fuels.

Having produced carbon monoxide and hydrogen, many types of synthesis are possible at fairly moderate temperatures. All these processes are exothermic so that heat recovery schemes will influence the overall fuel economy but it is only in the production of synthesis gas that the usefulness of nuclear fuels should be analysed.

Impact of nuclear heat on industry

The usefulness of these fuels will be governed by the following:—

1. The scale of application will have a very pronounced effect on the economics and the temperature that can be achieved in nuclear reactors will govern the reactions that can be considered. The development of cheaper, smaller reactors and the achievement of higher temperatures will both favour the use of nuclear fuels.
2. The safety of reactors will have to be assured to a standard to make them acceptable for location in industrial environments.

All the reactors at present being developed aim to produce steam for use in turbo-alternators. If process applications can use the same reactors, preferably producing power as well as useful heat, this would be very desirable in view of the high cost in finance and manpower involved in developing nuclear reactors. However, it is suggested that this should not be accepted as an overriding limitation at this stage. The object should be to determine where nuclear fuels are most likely to be useful and what specifications are likely to be put on the nuclear reactor. When this is done the best method of meeting the specifications can be assessed.

The Nation's heat

SIR SYDNEY FREW
Ministry of Power

Wherever steam is needed, it usually pays to generate it at a high enough pressure to make by-product mechanical or electrical energy, because of the important economies in fuel usage resulting from the use of steam for power production combined with its use for heating. Power generation from a back pressure engine or turbine can realize thermal efficiencies as high as 70 to 80 pct where there is a requirement for power and heat, whereas condensing engines do not in general convert much more than a fifth of the heat in the fuel into power. One of the largest users of process heat is the pulp and paper industry in which 6 pct of the total value of the end product is in the cost of fuel and about 2 pct in the cost of electrical power used. About 80 pct of this heat is obtained from engine exhaust steam. Norway is actually building a 10 MW reactor to be used in its pulp industry, partly for power and partly for steam processing.

The average cost of fuel to industry is about 7 pct of the value of the goods produced, but there are considerable variations in fuel costs between the different industries. In the industrial drying field, such as in the large centralized processes of brick making and cement manufacture, where the heat required is at only a few hundred degrees centigrade and fuel costs are paramount, cheap heat supplies could be most helpful in meeting the special drying-cum-fuel problems.

District heating

Sweden is planning two reactors for District Heating—one to produce 90 MW of heat and the other for 13 MW of electrical power, plus 71 MW of heat, the latter involving higher temperature and pressures. In the post-war years, a number of District Heating schemes have been developed in Britain—most of them on small housing estates of between 90 and 900 dwellings—but the high cost of heat distribution is a major factor militating against them and it is apparent from a capital cost point of view that if the problem is to be re-examined in the light of nuclear energy as a new source of primary heat, the distribution system will have to be compact, and this would mean the nuclear station would have to be in the heart of a thickly populated area.

Chemical industry

G. NONHEBEL
Imperial Chemical Industries

The first large-scale use of nuclear fission in the chemical industry is likely to be for the provision of steam, together with all the electricity that can be generated from the installation without the addition of condensing alternators.

Since it may be assumed that the power requirements for the nuclear plant would in any case be generated on site with ample spare capacity, it becomes apparent that generation of additional electrical requirements of the factory will always be an economic proposition when the power is obtained from back pressure turbo-alternators. Moreover, since reactors would not be installed in factories until it has been proved that they need no longer be installed in remote areas, it is for consideration whether public supply condensing power stations should be installed adjacent to chemical factories with large combined steam and electricity requirements where there are also available sufficient land and the necessary water for cooling water service. Immediate proximity is not essential since recently the steam supply to three chemical factories has been reorganized and is now successfully supplied from one factory by pipe lines of 7,000 and 5,000 ft for pressures of 200 and 10 lb/in^2 respectively.

Two problems of atomic power stations are the need for high load factor and the desirability of exporting low grade heat instead of dissipating it in cooling towers. Adjacent heavy chemical factories to which steam and power are supplied would reduce the magnitude of these problems.

Coal industry

W. IDRIS JONES
National Coal Board

Coal is cheap in comparison with the other fuels used in Britain the comparative prices at present being approximately:

	Coal	Coke	Heavy Oil	Gas Oil	Electricity	Gas
d/Therm	5	7	9	11	50	19

These figures gives us a lead to the integration of supplies of heat from nuclear sources and from coal. The present route to high temperatures from nuclear heat is via electricity, which is intrinsically very inefficient. We should therefore use coal or other fuel directly for high temperature purposes wherever possible. Much of our best large coal goes to its socially valuable but technically degrading use of space heating. Any waste heat from nuclear reactors could do this work just as well, subject to location and transport.

A simple potential colliery application of nuclear heat is the washing of coal. To evaporate the water from 1000 t/day of coal containing 30 pct H_2O requires over 10 MW of heat at 70 pct efficiency of use. Assuming a 10 tMW reactor, a capital cost of £M1 and a 100 pct load factor, the drying cost per ton of dry coal would be about 8 shillings. If the capital cost were £M3 the drying cost would rise to 22/- or so per ton of dry coal. Standard plants today can dry filter cake containing 30 pct moisture at a cost of about 6–7 shillings per ton, but they do so at the expense of using coal as fuel.

As to the suggested use of nuclear heat for carbonizing coal in coke ovens and retorts, a 1500 t/day coke oven battery would require roughly 55 MW of heat at a temperature of about 1200°C. A low temperature carbonization plant would require rather more heat than this but at a temperature of 700°C.

Gas industry

SIR CHARLES ELLIS
The Gas Council

I have an instinctive feeling that when we are at the beginning of an important new application of technology, it cannot be right to use it for what might be called ordinary purposes. The first entry of nuclear energy power into industry for other than making electricity should be to produce something of high intrinsic value or of high intrinsic quality.

I leave aside the question of the really high temperatures for which there would be many applications and in considering the temperatures which we have heard may soon be within reach, it seems that the gas industry's new hydrogeneration process of oil or coal is one that is worth thinking about. The reaction itself is exothermic and is carried out at a pressure of about 30/35 atmospheres.

That process is under development on the large scale and we hope that in a matter of a few years it will be a practical proposition. If so the natural development will be to erect large plants and take the advantage of siting anywhere on the trunk mains.

The requirement for this application is hydrogen and the main method at present of making it in industrial quantities is by partial oxidation of coal or any carbonaceous matter in the presence of steam. This produces a mixture of carbon monoxide and hydrogen and the next step is to use the water gas shift reaction and make more hydrogen from water by oxidizing this carbon monoxide to dioxide. It will be noted, however, that this method of making hydrogen results in converting carbon atoms, that is fossil fuel, into carbon dioxide and throwing them away. It is precisely this waste of valuable carbon atoms that can be avoided by some new process in which the heat of an atomic reactor can be used to split up the water molecules.

Water Distillation

J. LEICESTER
British Launderers Res. Ass.

We in this country think of water as a fairly cheap commodity, two to four shillings a thousand gallons, but in some remote areas of the world—for example, in parts of Australia water is transported over long distances for stock raising or for supporting some small farming community—costs are in the region of £10 to £13 a thousand gallons.

Cost estimate for the evaporation of water

	£M
INVESTMENT CHARGES	
Capital cost of reactor-boiler	33·25
Capital cost of evaporator, heat exchanger, pumps, etc.	6·00
Fuel investment in plant (taken as £4,000 per MW of heat	4·76
	£44·01 million
ANNUAL CHARGES	
Capital (amortized over 20 years)	2·20
Annual fuel rental (taken as 5 pct of initial fuel cost)	0·24
Operational Labour	0·22
Separation of fuel	0·17
Fabrication of fuel elements	0·25
Pumping costs for condenser cooling water (taken at 5d for 1,000 gallons)	0·21
	£3·29 million

Consider a nuclear-heated distillation plant with a throughput of 40 million gallons of fresh water per day (fig 4). This is equivalent to about 1000/1350 MW of heat from the reactor and gives the cost estimate above.

As expected, there is very high capital cost for the reactor boiler; costs for evaporators, heat exchangers, pumps, etc., are a relatively small proportion at £6 million, and there is a figure of approximately £5 million for the fuel investment. Taking that investment charge and the annual charges of appreciation of capital over a period of 20 years, we find our total annual charges for 40 million gallons per day would be approximately £3·29 mil-

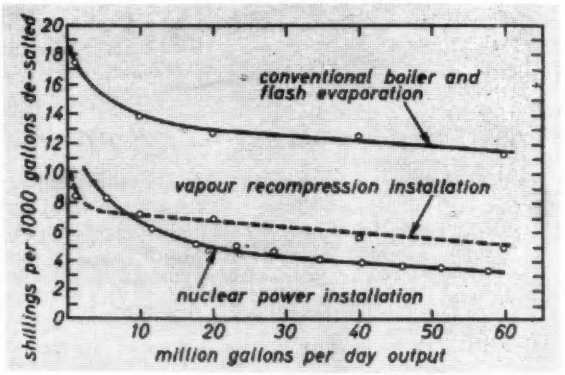


Fig 5 Assessment of probable de-salting costs

lions, or 4·4 shillings per thousand gallons. At an output of about 10 million gallons per day, the cost of water produced (fig 5) is beginning to drop in price below its nearest competitor, the vapour compression evaporator. With these large quantities, even 1/- per thousand gallons may make all the difference between economic possibility or not.

The rather high cost for the conventional boiler and flash evaporator is because installations of this type may be erected miles away from civilization and fuel costs may have to be very high due to transport charges. I have not considered any other form of evaporation because the multi-effect flash type evaporator is, I think, the obvious one that would tie into this scheme. It is a very efficient user of low grade heat and it would be the most economical system to consider for the proposed application.

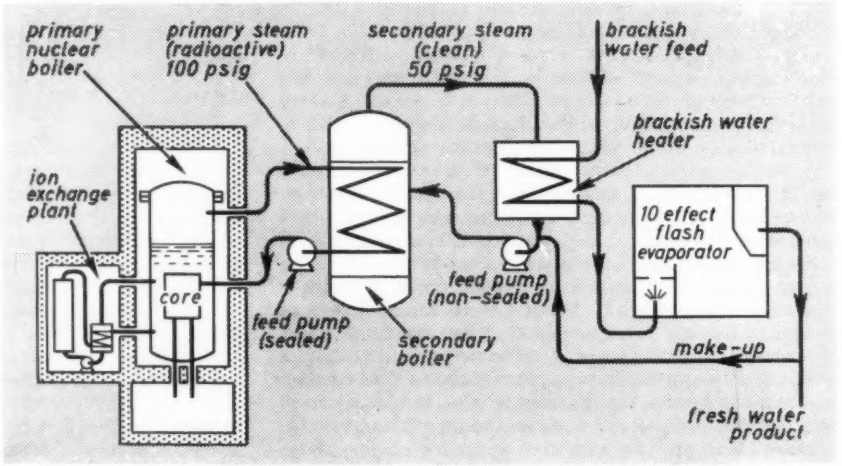


Fig 4 Scheme for a boiling water reactor uses secondary steam to distil brackish water. Temperatures needed would only be about 170–190°F. For an output of 40 million gallons a day a 1000 tMW reactor would be needed and the cost is estimated at just over 4 shillings a thousand gallons, which would be very cheap in some parts of the world. A verbatim report of this symposium is contained in Harwell report CE/R 2257

With her abundant native uranium deposits and proposed high-burnup heavy-water reactors, recycling has little attraction for Canadians

IS FUEL REPROCESSING NECESSARY?

for Canada the answer seems to be 'no'

W. B. LEWIS
Vice-President Research and Development, Atomic Energy of Canada Ltd

TEN OR ELEVEN YEARS AGO the Canadian atomic energy project shared the view that the future development of large-scale nuclear power depended on breeding an increasing stock of fissionable material. All reactors then known were supposed to become choked with their 'ashes,' the fission products, so that relatively frequent chemical extractions would be necessary to recover the fissionable material and make it up into new fuel elements.

Today we envisage operating a generating capacity of tens of millions of kilowatts without necessarily any spent fuel processing.

In the meantime we have gained experience of extracting many kilograms of plutonium and making several kilograms up into fuel elements and re-irradiating some and re-extracting the plutonium. That is as far as we have reached, but it appears to be further than anyone else in the world has yet gone.

Recycling not essential for Canada

For certain special purposes we are still keenly interested in this spent fuel processing and recycling, but we do not regard it as essential for meeting our own power needs for the next 30 years or so. Shortening our horizon to ten years, we do not foresee that we will need greatly to expand our plutonium extraction facilities as long as concentrated fissionable material remains available to us from larger and more economic installations in other countries. We do not, moreover, necessarily expect to be self-sufficient in processing. If we can get any processing steps carried out in other countries at a lower cost, we would avail ourselves of the service.

The position may be simply stated. Contrary to the expectations of ten years ago, such an abundance of uranium has been found in the world, particularly in Canada, that even if we extract only one per cent of its total content of fission energy, we can maintain a generating capacity of 50 million kilowatts without even using all our present production. In fact, our uranium miners are fearful of lean times ahead because of the many years before nuclear power installations in the world reach even this 50 million kilowatt generating capacity.

There is a mistaken view sometimes expressed that extracting only one per cent of the total fission energy from uranium is to be compared to 'high grading' at a mine. This is not so because the spent fuel is not a 'low grade' product; it is just as available for future economical use as if a recycling or breeding operation were used from the start. Indeed, it is more readily usable if it has been left for some of the more radioactive fission products to decay.

The practicability of extracting one per cent of the fission energy from natural uranium without reprocessing must be regarded in itself as a high technical achievement, attainable only in large power (e.g. 200 eMW) heavy-water-moderated reactors. The high energy yield or burn-up obtainable contributes towards making this type of reactor economically the most promising. In other types of reactor, however, 0·3 pct should be obtained, and there is no prospect of running short of uranium in the next 30 years, or even much beyond that.

As long as natural uranium is available at about its present price or lower, there may be no economic advantage in extracting plutonium from spent natural uranium fuel.

For economic reasons it seems almost certain that the first large-scale development of nuclear power in Canada will be based on natural uranium and will not require any spent fuel processing. This will hold for all reactors commissioned within the next 12 to 15 years. The only departure from this would arise if industry could offer without any capital advances to extract and purify the plutonium and recover the uranium free of fission products for about \$8/kg of uranium or about \$2.50/g of plutonium, but depending on the content. Then for fabricating this plutonium into fuel elements, the allowance would be about \$5/g of plutonium for Zircaloy cladding and less for materials that absorb more neutrons. The scale of the operation foreseen would not rise to one ton of uranium a day before 1970. This prospect has not seemed attractive to industry. Operations would have to be on a larger scale and with a more certain through-put to make it possible.

and the date of 1970 is so distant that it is too early to call for the necessary investment.

Plutonium best for breeding

In the longer term the prospect for spent fuel processing is much brighter. The major use for plutonium appears to be as an intermediary in the production of uranium-233 which does not occur in nature and cannot be produced at all cheaply in natural uranium reactors.

To the physicist the production of U-233 is seen merely to require neutrons, and the best yield of spare neutrons is obtainable from the fission of plutonium in fast neutron reactors, such as the sodium-cooled fast breeder reactor being built on Lake Erie by the Power Reactor Development Company, Inc. Otherwise U-233 may be produced in thermal reactors by making up a special fuel of thorium with either U-235 or plutonium. Usually U-235 seems preferable if available at the current rates in the USA, but if one has any special reason, plutonium can be used instead.

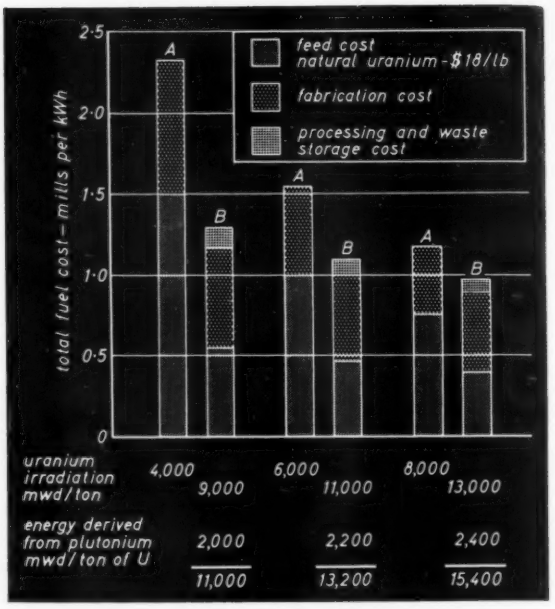
In this, however, I am looking many years ahead to the time when high temperature, gas-cooled reactors using the U-233: thorium cycle are producing tens of millions of kilowatts so that their fuel reprocessing reaches an economic scale. For, alas from the fuel processor's viewpoint, the special virtue of these reactors is that they may operate for ten years without any fuel change.

Poorest reactor needs recycling most

This referred to the major long-term use of plutonium, but in the shorter term other uses seem quite possible if only the processing costs can be kept low enough. This may be illustrated by comparing fuelling costs for three different reactor designs needing different levels of reactivity, or excess of neutrons from the fuel (see figure). When fuelled with natural uranium without reprocessing, these would be limited to 4,000, 6,000 and 8,000 MWD/tonne U, but if the plutonium is extracted and recycled at the cost I have mentioned, the total burn-up is extended to 11,000, 13,200 and 15,400 MWD/tonne. The point is that for the poorest reactor the economy derived from recycling is greatest. Now all these reactors are capable of operating on natural uranium, but many designs, especially for the smaller reactors, require more spare neutrons, and may even require enriched uranium. In this case the economic advantage of recycling is still greater.

How many such reactors are likely to come into operation? It seems unlikely that there will be many in Canada, but the possibilities are not negligible in countries where alternative conventional fuel costs are high and where the largest reactors are not required, and provided that fuel processing becomes accessible to them. Canada, as a uranium producer, has an interest in such possibilities.

It may be of interest if I outline our experience in the extraction and recycling of plutonium as reactor fuel. On the kilogram scale, we have developed and employed three different primary extraction processes and three plutonium purification processes. All are much too costly, working out at over $50/g of plutonium, but do not represent what we would build for a new plant. When we started up in 1949, the plutonium was extracted by triglycoldichloride from the nitrate solutions, using ammonium nitrate as a salting-out agent. Later we changed to uranyl nitrate as the salting-out agent to stop accumulating all our fission products in ammonium nitrate. We also recovered the uranium from the earlier extractions by tributylphosphate extraction, decomposed the ammonium nitrate, and concentrated the fission products. At that time, the plutonium purification was a double process of hexone extraction and



EFFECT OF RECYCLING PLUTONIUM ON TOTAL FUEL COSTS A is for once-through operation: B is plutonium recycled once with 50 pct burnup. The three uranium poison limits represent different reactor designs

thenoyl-trifluoracetone purification. For simplicity later we developed an anion resin exchange process for the direct extraction and purification of plutonium. We have also used this process for the re-extraction of plutonium from the irradiated plutonium-aluminium alloy fuel elements.

Need for plutonium not seen as urgent

Our present programme is to keep irradiating 3 kilograms of plutonium a year in the NRX reactor with several purposes. First it gives us experience. It also provides extra reactivity to compensate for other loads in the reactor. It also gives us the higher isotopes of plutonium that are in demand by the physicists for determining how they will affect reactors and by the chemists as sources for preparing other transuranic isotopes.

I have mentioned these things to illustrate that while we find plenty to do with plutonium, it is all on an experimental scale, and does not yet seem ready for industrial expansion. It is, however, probably important to keep the technology alive so that if the power programme opens up a requirement, the technique will be ready.

The demand may arise at three points—

For the smaller power reactors required in places where conventional fuel costs are high. This probably will involve shipping the spent fuel between countries since the total needs can be met by relatively few processing plants

When a rise in uranium costs or a lowering of processing costs makes it advantageous to extract more than 0·5 to 1 pct of the fission energy from uranium

For power reactors using the uranium-233: thorium cycle

These are the requirements as seen from Canada. I recognize that the US preference for enriched uranium reactors for most purposes involves more processing of spent fuel for uranium-235 recovery as well as for plutonium.

This article is based on a lecture given in New York last October to The Atomic Industrial Forum.

Weakness in the Operations Branch of the AEA's Industrial Group was one of the factors blamed for the Windscale accident, and the Prime Minister ordered a check-up of its structure and staffing

'Make new top-level posts, concentrate on operations'

—Fleck Committee recommends

Chairing the committee was Sir Alexander Fleck, chairman of ICI since 1953. Led the advisory committee which reviewed the organization of the coal industry and in 1955 produced the well-known 'Fleck Report.'

C. F. Kearton, part-time member of the UKAEA since 1954, is chairman of Courtaulds and member of the Electricity Supply Research Council. Worked on diffusion plant in the war-time atomic energy organization 'Tube Alloys'

Sir William Penney was assistant professor of mathematics at Imperial College from 1936–45 and loaned to the MoS for bomb research during the war. Now UKAEA member for weapons research and development

LACK OF TECHNICAL MEN in the Operations Branch, especially in senior posts, is the main weakness of the Industrial Group, and strengthening of the branch is essential, even at the expense of research and development. This is the most important conclusion of the three-man committee set up 'to examine the organization of certain parts of the UKAEA,' following the Windscale accident. Ever-widening commitments of the Industrial Group have left it undermanned at the top and this shortage is felt most severely in the Operations Branch. On the whole, the Engineering and Research and Development Branches have found it less difficult to attract sufficient recruits with the right technical background. The forward-looking work of these branches naturally has greater appeal and the job of giving technical advice on the operation of completed plant is not nearly so attractive, especially as rapid progress in the nuclear field often makes it seem out of date almost before it is finished. Also, as plant becomes more complex, there is a tendency for it to become more and more automatic and apparently needing only push-button control. In fact this is not the case: although a smaller number is required to operate these plants, the men must be more highly qualified than for less sophisticated operations.

Breakdown in liaison

Another result of the senior staff shortage has been inadequate liaison between the various branches of the Industrial Group and with Harwell and Aldermaston. Both these factors have been emphasized by the Windscale accident. The committee summarized the position by saying that the Operations Branch has become seriously out of balance with the Engineering Branch especially and with the Research and Development Branch.

Recruiting difficulties of the Operations Branch have been further enhanced by staff grading. When the Authority was set up in 1955, the Government decided that salaries of senior staff should not be seriously out of scale with other public corporations. This has made it difficult to get senior staff from established industry. It was also decreed that below senior level, ordinary civil service grading should be adopted, which has created difficulties in staffing the Operations Branch as a result of minor, but important, differences in the grading of scientific and engineering staff. Considerable thought has already been given to this problem by the Authority and the committee stresses its immediate urgency.

Criticism of the methods of the Industrial Group's Board was also made in the report. At the moment there is not

enough devolution of responsibility from the Production Executive Committee—this comprises the directors of all the Branches and serves to coordinate all the Group's activities—and the directors themselves. Joint discussion of major problems and policies of the Group should be the first job of the Board, say the committee. This will, of course, entail greater delegation to directors of responsibility for their own particular spheres.

Adjustment of priorities

Before the committee could make any recommendations to improve the organization of the Operations Branch, they had to consider the Industrial Group as a whole and, to a lesser extent, its relationship with the Research and Weapons Groups. They believe that the IG has four main objectives, and if the Operations Branch is to be strengthened as they think it should, the relative priorities of these must be readjusted. The committee states the Group's responsibilities, in order of importance, as follows:

1. to show that the large-scale plants it has in operation can be worked safely and efficiently; for this the technical strength of the Operations Branch must be increased
2. to ensure that the designs of the power stations now under construction are very carefully monitored and all available resources used to ensure their safe operation; this will require considerably increased technical staff.
3. the Dounreay fast reactor project
4. to study advanced reactor types.

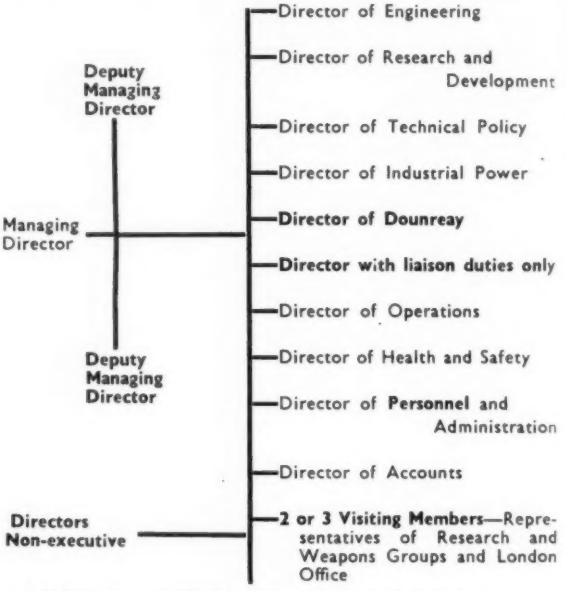
Paramount importance is attached to the first two, even if this means that work on some research projects has to be suspended and key staff transferred from other groups to Risley.

With these aims in mind and to overcome the deficiencies described above, a number of additions to the IG's Board are proposed. So that the managing director can be substantially free from routine duties and able to make contact with outside bodies, the committee recommend that he should have two deputies, also substantially free from executive ties, one particularly responsible for the Engineering, Research and Development, Industrial Power and Technical Policy Branches, and the other for Operations, Personnel, Health and Safety, and Accounts. Another new director is proposed to ensure liaison with Harwell and Aldermaston, universities, technical colleges, etc. To be chosen for his technical ability, he would have no executive duties and would be appointed for only a limited period of time. The fourth new post suggested is a member responsible for Dounreay because of the special difficulties of size, remoteness and functions of the plant. The committee emphasize that the staff at his disposal must be strongly technical and that the time scale and staffing problems of the project should be carefully reviewed in two or three years' time. A few visiting non-executive members—from the weapons and research groups, for instance—would also benefit the Board.

Importance of personnel work

Throughout the report, great emphasis is put on the vital role of the personnel department, in recruitment, training and promotion. Thus the committee recommends that the present post of director of administration should be renamed 'director of personnel and administration' and should, with its deputies, be upgraded. In charge of personnel policy for the whole Authority, he would foster interchange of staff between the Groups.

Considerable reorganization of the Operations Branch headquarters is suggested, and the report stresses that senior posts must be filled by men of proven technical ability. This applies to the director himself and to the two deputies proposed, one mainly for production matters and the other a technical deputy, who would control a technical department of four sections headed by a physicist, a chemist, an engineer and a metallurgist. Close liaison with the Engineering and Research and Development Branches would be one of the major duties of the technical deputy director and he and his staff should provide the link with technical staff at the factories to help works managers over maintenance and operation problems. Preparation of operational manuals


Director of Engineering
Director of Research and Development
Deputy Managing Director
Director of Technical Policy
Director of Industrial Power
Managing Director
Director of Dounreay
Director with liaison duties only
Director of Operations
Deputy Managing Director
Director of Health and Safety
Director of Personnel and Administration
Director of Accounts
Directors Non-executive
2 or 3 Visiting Members—Representatives of Research and Weapons Groups and London Office

Additions to the Board of the Industrial Group have been suggested by the committee. New posts proposed are shown in heavy type

will be done by technical staff at the works under the ultimate control of the works general manager. Besides detailed instructions for routine jobs, they should also include enough descriptive matter for plant operators to take an intelligent interest in their work.

Separate manager for Chapel Cross

On the various works themselves, the report suggests, as a general rule, that the unit under one man should be about 1000 people. In fact this principle has been adopted by the Authority and they have appointed a works general manager with a number of works managers under him. However, at the moment the Windscale WGM also controls Chapel Cross, 70 miles away, and the committee propose a separate post for this with responsibility direct to the Operations Branch HQ. Beneath the works general manager the chain of command should be clearly laid down and understood. The organization suggested for this includes a deputy and a works engineer responsible directly to the WGM. Technical support for the works management must be provided by scientific and technical specialists in all the relevant fields at each of the works. With wise leadership from the Personnel Branch and an increase in the number and status of posts in the Operations Branch, the committee believe that work in the Branch will be more attractive.

Included in the report is a review of reactor operation in the Research Group. The conclusion is that the existing organization is right in principle and adequate for the present purpose but that it will require constant review as the complexity of the reactors increases.

Reactor-grade zirconium metal

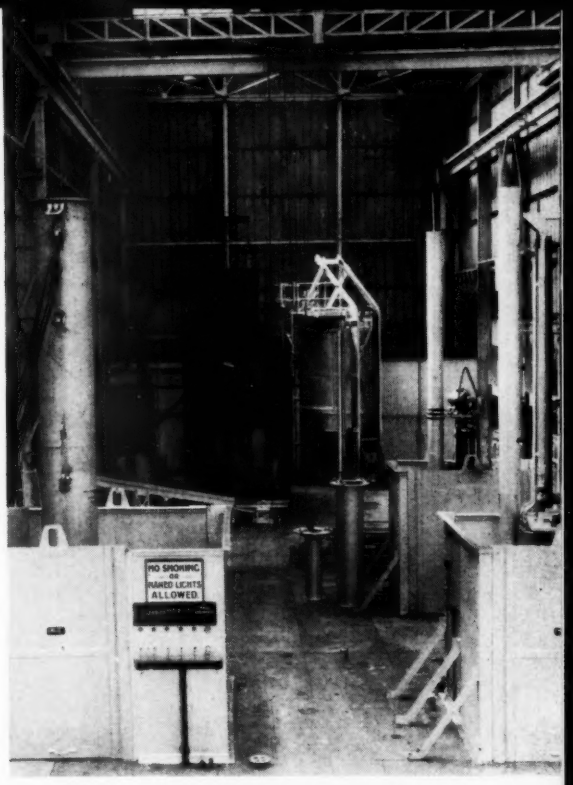
production starts at Sheffield works

AT THE SHEFFIELD WORKS of Wm. Jessop and Sons Ltd, a £300,000 vacuum melting plant was laid down in 1954 for the production of titanium and special steels. Since the consumable arc method is used for melting titanium it was appreciated that the same furnaces could readily be used for zirconium and, in anticipation of a demand for this metal for use as a core material in gas-cooled and pressurized water reactors, Jessops early this year announced plans for meeting it. Recently NUCLEAR POWER had an opportunity of visiting Sheffield and being shown round the plant. The process is of course a batch one, but ingots of up to 1½ tons can be produced if required with the existing facilities. A more normal size ingot of zirconium however would be 500 lb.

Compacting electrodes

The zirconium process starts witih crushed metal sponge obtained from both Murex Ltd in the UK and from American companies—notably US Industrial Chemicals and Wah Chang. This is all produced by the Kroll chlorination process and if the end product is to be of reactor grade, the sponge has to be hafnium-free (the USI spec. calls, for less than 0.1 pct). Owing to its pyrophoric nature the sponge arrives canned in an argon atmosphere and substantially free of fines—the grade in fact is about ¼ in. First the sponge is weighbatched in steel drums and then elevated to the top of a rotary distributor which fills eight hoppers with homogenized material. At this stage alloying elements—tin, iron etc in the case of the Zircaloys—are added in a rotary tumbler and then pressed into compacts in a hydraulic die press. The cross section of these is that of a semi-octagon and in the case of zirconium the width across the flats is 6 in.—weight, 25 lb.

The object of this is to build up the consumable electrode for the primary melt furnace. This is done on a horizontal roller conveyor and the half-octagons are first welded together by argon-arc and then five complete octagons welded end-to-end. The total weight of compact is thus 250 lb, two complete electrodes being used to produce a 500 lb, 12 in. ingot of zirconium. These dimensions and weights are however only typical: the system is actually very flexible in this respect. In melting titanium for example, in the same furnace, 12 in. electrodes are used to produce a 20 in. dia ingot of about a ton. At the top end, the electrode is welded to a long fabricated steel cage of the same cross-section which runs in guides. The cage engages in the chain-driven electrode feeding mechanism and the whole assembly is contained in a long cylindrical tank forming part of the vacuum system. By this means no mechanical motions have to be taken through vacuum seals. The electrode tank is mounted on trunnions and when it is loaded it is then raised into the vertical position.



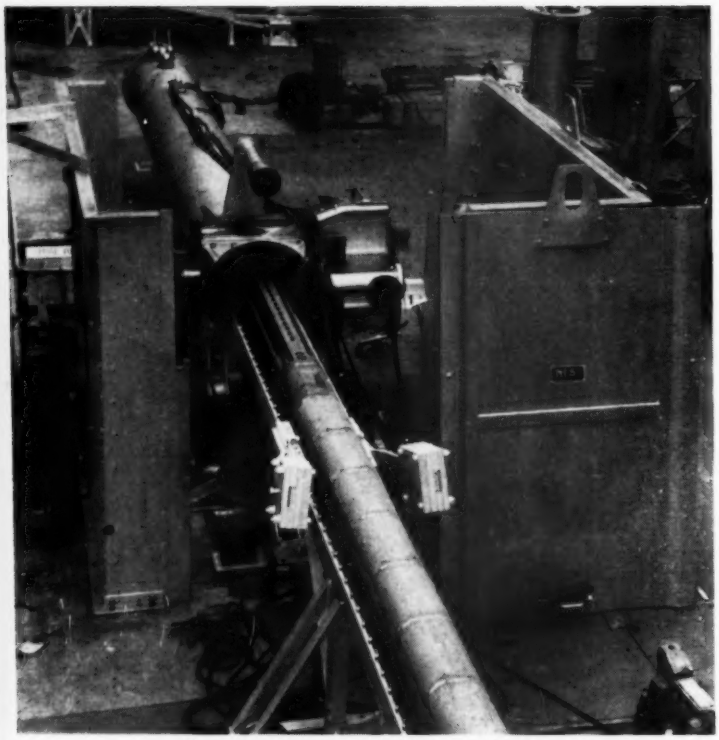
The whole process is carried out in this shop. Zirconium sponge is first homogenized in the distributer at the far end, then it's compacted in the hydraulic press and welded into consumable electrodes. These are melted in the primary furnace (right) into copper moulds and the resulting ingots remelted in the smaller furnace (right). Since this shot was taken preparations were started for installing a much larger furnace in front of the press

Remote control

Crucibles used in the process consist of double-skinned thick copper cylinders with water circulation through the annulus; these are of various diameters up to 20 in. depending on the melt required. They are contained in a steel tank below floor level fitted with a flange which mates with that on the bottom of the electrode tank when it is raised into the vertical position. At the bottom of the crucible is placed a 'stub' of the metal to be melted. This gives the electrode a start and also forms an important feature of the second melting operation.

When the crucible has been prepared and the electrode tank put in position the furnace is pumped down to a vacuum in the range 5-20 microns and the arc struck. The electrode feed is controlled by a Metadyne system to ensure a constant voltage of about 30 volts. Current in this primary melting furnace is of the order of 20,000 amps and is supplied from a bank of Westinghouse selenium dry disc rectifiers in an adjacent part of the stop. During melting the furnace is screened off by removable metal partitions, operations being controlled from cubicles in the rectifier bay. These include instrumentation for electrode position, current, coolant water temperature, vacuum etc.

After controlled cooling the crucible is removed from the pit and the ingot, complete with its stub, removed. Great importance is attached to cleanliness of the crucibles and after use they are thoroughly wire brushed down to bright metal. This concludes the primary stage but to



Compacted sponge is welded together in sections and fed horizontally into the electrode feeding mechanism. The tank will then be raised vertical and its flange bolted to that on the crucible-containing tank. After pumping down in a vacuum, the arc will be struck and the sponge melted to an ingot.

ensure perfect homogeneity—particularly in the case of alloys—a further, remelt stage is employed.

This is also a consumable arc process using as an electrode the ingot from the first melt. The stub mentioned previously is a massive disc of the melt material and the same diameter as the ingot. It is fitted with holes by means of which it is attached by bolts to the lower end of the electrode feeder of the remelt furnace.

This is basically similar to the primary furnace but the electrode feeder is a chromium-plated copper ram running through a vacuum seal on top of the furnace and driven by a Metadyne constant voltage control system through a rack-and-pinion mechanism. It is to the bottom end of this ram that the stub of the primary ingot is attached. Remelt crucibles are similar to primary ones but are shorter and of greater diameter since of course the primary ingot, now the electrode, has to have adequate clearance.

Final treatment of ingots

The vacuum system for both furnaces is located in a room below floor level. It contains seven Kinney rotary pumps and an Edwards oil-diffusion booster pump. Since zirconium is a very strong ion-getter no purification can be obtained by vacuum as is the case with steel melting and it is used rather as a means of preventing the metal picking up any further impurities.

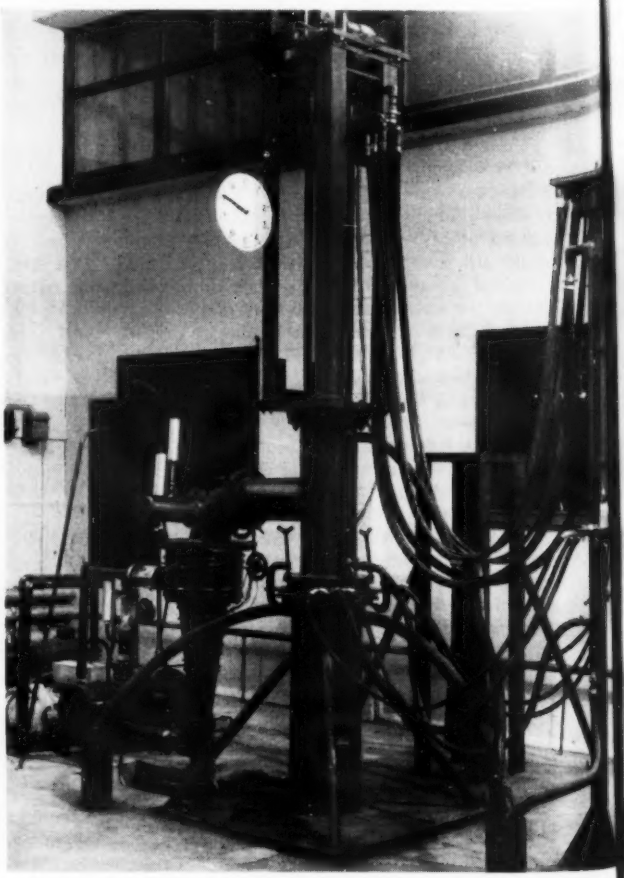
On extraction from the crucible the ingots are very rough at the ends and on the surface and they are therefore scalped in a lathe before further work, local surface imperfections remaining being removed by grinding. Subsequent work on the metal can consist of slabbing and rolling for sheet or strip, or billetting for forging, drawing or turning.

Alloys under development

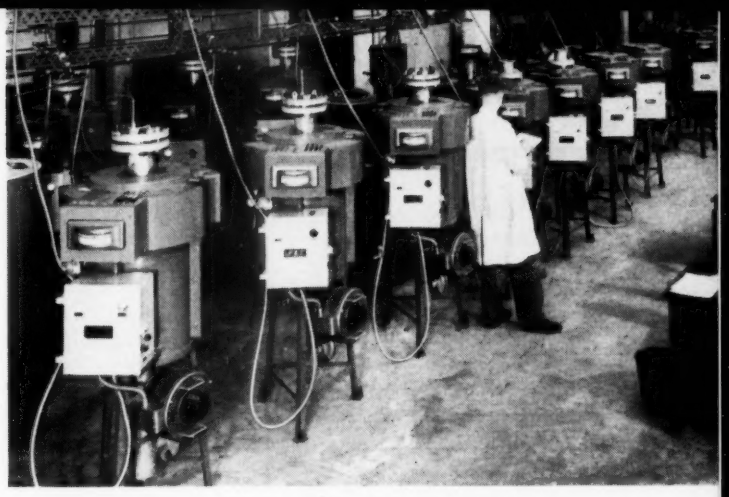
Jessop's have for many years believed in research and in 1950 set up a laboratory at Whiston Grange, near Rotherham, in which a team of 50 is at work on long term investigational and development work. Creep testing has figured very largely in the work and with over 200 creep units, the firm claim theirs to be the biggest private installation of its kind in the UK. Some current work is devoted to newer alloys of zirconium. The consumable arc vacuum melting furnaces were developed in the laboratories and the pilot model installed here is capable of producing 6 in. ingots.

At the works, preparations are currently in progress to install a very large furnace of this type. Unlike the existing units which were all built within the firm, the new one will be supplied by W. C. Heraeus GmbH of Hanau, Germany.

Current world prices of zirconium sponge are showing a steady dropping tendency with US figures in the lead and thus the position in this country is somewhat fluid. However substantial demands for reactor-grade material are expected to consolidate during this year for power station construction and Jessops are ready to meet it. As to commercial grade metal, this of course will be very much cheaper. As yet there is little sign of any substantial demand but the firm are hopeful that this will develop as the advantages of the metal as a corrosion-resistant material become more widely appreciated. Wm. Jessop & Sons Ltd is a member of the BSA Group.



A pilot model of the production vacuum furnace was built at Jessops research laboratories near Rotherham. This is similar to the remelt furnace in the works but there the vacuum system is below ground



This battery of twelve units is installed in GEC's Atomic Energy Division at Erith for preliminary creep and stress-rupture tests on materials under simulated conditions of reactor temperature and pressure

Quick results aim of new GEC creep facilities

NEW RESEARCH EQUIPMENT designed to provide preliminary creep and stress-rupture data on metals and alloys in gaseous atmospheres at high temperatures and pressures has recently been installed in the materials research laboratory of the GEC Atomic Energy Division at Erith, Kent. Twelve creep-test units have already done valuable basic work in investigating the properties of magnesium alloys—widely employed for fuel element cans—in carbon dioxide atmospheres. They can be readily converted for future work to deal with other materials in other gases.

This equipment has been installed to meet the requirement for applied research facilities beyond the range of normal metallurgical laboratory equipment. This requirement arises from the urgency of the British nuclear power programme, which demands that investigations be carried out at a much greater pace than is usually imposed on metallurgical development work.

Machines for carrying out creep tests in air are standard items of laboratory equipment, and it is comparatively easy to adapt such machines for operation in other atmospheres by enclosing the test specimen in a gas-tight vessel through which the pull-rod passes via a gas-seal. This arrangement can, however, be used only at atmospheric pressure, and while the results obtained can be of definite value, it is highly desirable to investigate the effects of gas pressures such as prevail in a reactor circuit.

Rapid assessment of reactor materials

The battery of units now installed at Erith was designed for a specifically limited purpose. It is not claimed that it can be used for a complete investigation into the creep behaviour of materials under reactor-operating conditions. Within the time-factor imposed, however, it does provide an efficient means of obtaining, very rapidly, a broad assessment of the suitability of materials for reactor service. More detailed investigation can then be undertaken on materials which pass this preliminary test. Within these limits, the equipment has proved capable of remarkably consistent and reproducible results which are of great value in the implementation of a speedy and efficient nuclear power development programme.

In this new equipment, the specimen, the whole of the stressing apparatus and the associated extensometer are enclosed in a vertical cylindrical pressure vessel. This, in turn, is enveloped along part of its length by an electric furnace. The body of the pressure vessel, which is of stainless steel $\frac{1}{8}$ in. thick, is approximately 5 ft long and has an internal diameter of 4 in. At its open upper end it is provided with a machined facing flange. The top plate of the vessel is bolted down to a loose flange slipped over the vessel body, a Klingerit gasket being inserted between the top plate and the facing flange to ensure gas-tightness.

The upper end of the support rod, from which the specimen is suspended, is welded to the centre of the top plate, while its lower end is provided with a pivoted coupling, a similar coupling being fitted to the top of the pull-rod. Alternative couplings are available such that specimens of either rectangular or circular cross-section can be used. A cylindrical cup, which is a loose fit in the pressure vessel, is welded to the support rod between the top plate and the coupling and is filled with refractory cement to provide heat insulation above the operating section.

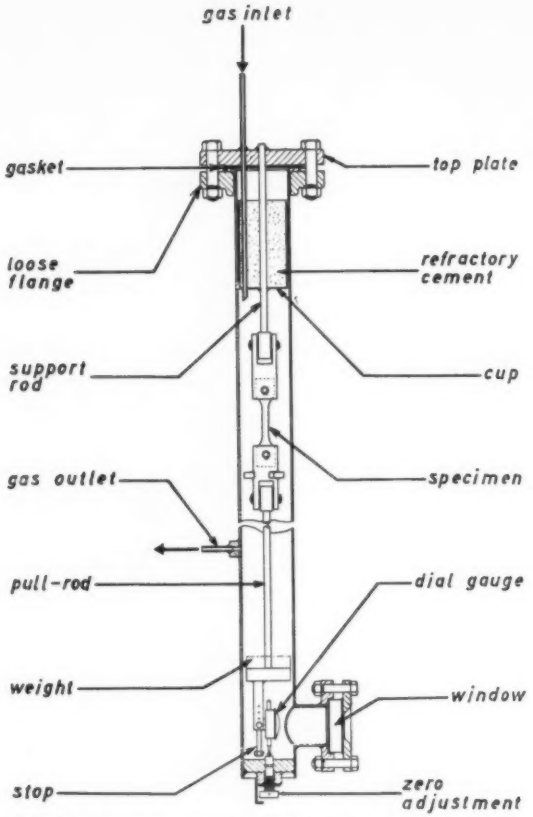
Furnace in two sections

The loading weights are mounted on a plate welded to the lower end of the pull-rod. To the underside of this plate is attached a bracket carrying a dial gauge, whose operating head rests on the end of a bolt passing through the bottom plate of the pressure vessel via a rubber gas-seal. The bolt serves as a zero-setting device for the gauge. The gauge reading can be observed through a pressure- and heat-resistant glass window mounted between soft rubber gaskets in a tube welded into the side of the pressure vessel. A stop is provided beneath the gauge mounting to prevent excessive travel of the pull-rod, which might damage the gauge, in case of rupture of the specimen.

Gas is admitted to the pressure vessel through a tube of $\frac{1}{4}$ in. i.d. passing downwards through the top plate and the refractory cement plug. A gas outlet tube, of the same diameter, is welded into the side of the vessel below the operating section.

The 4 kW electric furnace is built in two sections, and can be split by unbolting two vertical clamping plates, thus allowing the pressure vessel to be removed. The nichrome heating elements are carried in slots in the inner faces of bricks of high-temperature insulating material which are assembled in the form of a hexagon surrounding the pressure vessel, the space between the element bricks and the furnace casing being filled with refractory cement. The vertical wound length of the elements is 21 in. which gives an entirely satisfactory temperature distribution in the region of the specimen.

The two heating elements, one in each half of the fur-



Cylindrical pressure vessel containing test rod is 5 ft long, 4 in. dia.

nace, are connected in parallel to a 240 volt, single-phase, 50 cycle supply, the leads being brought out through the element bricks to terminal blocks mounted in ventilated chambers built round the top of the furnace casing. Connected in the supply circuit are a main contactor, housed in a cubicle mounted on the furnace casing, and a *Variac*. The latter is used for coarse regulation of the furnace supply, particularly during the warming-up period.

Sensitive temperature regulation

During normal operation, two chromel alumel thermocouples are employed. One is mounted directly on the specimen and is usually connected to a recording instrument, its leads being taken upwards through the gas inlet tube from which they issue through a gas seal. The second is mounted adjacent to the furnace winding and is connected to an Electroflo temperature controller housed in a louvre-ventilated casing built into one of the two terminal chambers. With this arrangement, extremely sensitive regulation of specimen temperature has been achieved.

When the stressing apparatus, with the test specimen mounted in position, has been lowered into the pressure vessel, the top plate is sealed down. The vessel is then thoroughly flushed with the gas being used as the test atmosphere before being brought up to pressure. The supply to the furnace is adjusted by means of the *Variac* to raise the temperature of the specimen rapidly to the required value, and it is then maintained at this level, to a fine degree of accuracy, by the temperature controller.

When stable conditions have been established, extensometer readings are taken at suitable intervals, the results being plotted as percentage creep against time. The total duration of the test varies according to the particular requirements, but is normally between 150 and 1500 hours.

Low temperature welding—Eutectic's methods demonstrated

IN 1904, a Swiss metallurgist, J. P. H. Wasserman, observed the phenomenon of surface alloying during brazing and he set up a laboratory to study it. Later, his son Rene D. Wasserman joined him and in 1940 went to the United States and founded the Eutectic Welding Alloys Corporation. In 1957 a branch was established in Britain—Eutectic Welding Alloys Ltd—and today it is expanding rapidly. We recently had an opportunity of visiting the Feltham factory where a demonstration of Eutectic's methods was kindly laid on by managing director F. A. Field.

Eutectic's method is basically the joining of metals by means of a low temperature alloy—not strictly a eutectic and in most cases a complex alloy. The advantages of this is in the low temperature required which simplifies work, preserves the parent metals from structural changes, prevents distortion or cracking of the job, and makes extensive preheating unnecessary. This introduces the idea of bonding temperature, which is the minimum temperature to which the parent metal must be heated at the surface to obtain a bond with the filler metal. For example cast iron metals at 2300°F, but it can be joined at 1300–1600°F using Eutectic's cast-iron filler metal which readily alloys to the surface at this temperature, no melting of the parent metal actually occurring.

This method of joining is used both with gas and electric welding equipment. With gas the alloy is in the form of plain rods and for each rod there is a corresponding flux which is generally in the form of powder although there are some pastes which combine alloy and flux. Metals joined this way include aluminium, magnesium, copper, brass, cast iron, steel etc., and dissimilar metals may also be joined. For arc-welding, flux-coated electrodes are used similar in appearance to normal products, the difference being that substantially lower currents are needed. A cutting and boring electrode is also available.

As a demonstration we saw two $\frac{1}{4}$ in. bolts welded end to end by the tips. After cooling one head was set in a vice and the other twisted by a wrench. This specimen sheared after about one turn—but not at the weld. Mr Field told us Eutectic have up till now concentrated on maintenance applications but that now they are expanding into the productive field—and this includes atomic energy.

Badly damaged, this cast-iron gear casing was repaired by arc welding using a current of only about 90 amps with no preheating. The welds were easily machinable

Chopper converts low-power signals

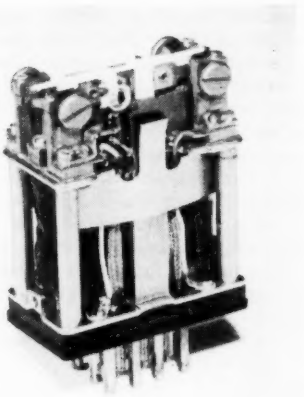
An a.c. miniature polarized chopper, believed to be the first in this country incorporating two changeover contacts, has been specially developed by Ericsson's for conversion of low-power signals and/or amplification in devices such as computers and servo-mechanisms. The two-changeover feature will find many applications where the rectification of signals is necessary. The contact system can be either make-before-break or break-before-make.

If required any minor adjustments to suit individual circuit requirements can be easily made by means of the readily accessible contact screws. No further adjustment should be necessary until after several thousand hours when an additional contact trim will prolong the life of the chopper indefinitely.

As a result of the Ericsson patented magnetic system, extremely low driving power is required, the effect of which together with the complete isolation of the contact assembly from the driving flux make the chopper practically free from any electromagnetic pick-up. Further, by careful screening, and good space relationships, electrostatic interference is rendered negligible

This new chopper is believed to be more compact and less expensive than any other similar instrument, and it will find many applications in the field of nuclear instrumentation.

Ericsson Telephones Ltd,
High Church St,
New Basford, Nottingham



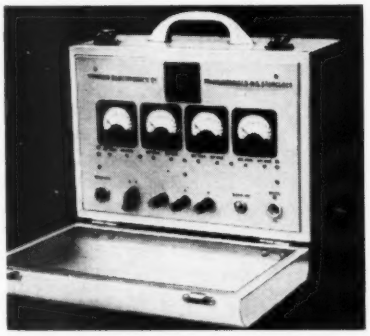
A long time between adjustments

Transistorized stopclock in a suitcase

New from Venner is a millisecond stopclock—type TSA4—designed for all types of time measurement and covering the range from 0·1 mS to 27·8 hours. The instrument is constructed from nine transistorized packaged stages. The basic time reference is a transistorized crystal oscillator operating at a frequency of 10 kc/s. Pulses from the oscillator are passed via a gate to four transistorized decade counters, and thence to a cyclo counter. The division ratio provided by the four decades is 10,000, therefore the cyclo counter receives 1 pulse/second. The elapsed time can be read in seconds from the counter, the four decimal places being taken from the meters calibrated 0-9 which in turn are connected to the decades.

The gating is arranged so that the closed or open times of contacts can be measured, or the time between one pair of contacts opening or closing and another pair opening or closing. Pulse operation is also catered for, as a positive pulse can be used to start or stop the instrument. The facility enables relay timing to be accomplished among many other applications.

Forty-six transistors are employed in the instrument but the consumption is only 1 watt at 12V. The instrument is fitted in a lidded case which measures 13 by 9 by 7½ inches. A battery carrying case is available for portable operation, and a transistor stabilised power supply can be used for mains operation.



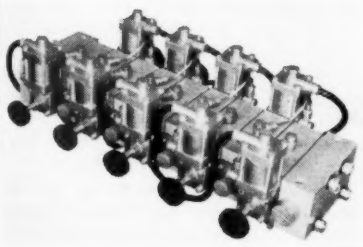
Completely portable, the stopclock covers intervals from less than a millisecond to many hours

Venner Electronics
Kingston Bypass
New Malden, Surrey

Piping clean-up for multiple control valves

Where a number of main control valves are used in pneumatically or hydraulically operated machinery, the problem of providing inter-connecting piping for supply and exhaust connexions becomes acute, particularly where space is limited, and the pipe size is relatively large. Also, the user is faced with the necessity of expending a great deal of material and labour in providing these inter-connections.

Baldwin's Fluid Power Division have now found a neat and economical solution by grouping the control valves at a central point in such a way that these inter-connexions are eliminated. The valves, which may be fitted with manual, mechanical, electric solenoid or pilot operating mechanisms, are supplied as a multipoint 'packaged unit'. Any number up to a maximum of 12, can be embodied into a single unit. The supply and exhaust ports of all the valves are led into passages running the full length of the assembly, screwed connexions being provided in special end pieces, which also provide facilities for mounting the the assembly as a whole. Each end block contains one supply and one exhaust tapping, which are common to all valves. Tappings in each individual valve body provide flued take-off points for solenoid pilot heads, where these are used. Each main control valve is therefore an en-



Packaging eliminated 15 connecting pipes in this 8-bank solenoid-controlled pneumatic unit

tirely independent unit from the functional point of view. This facilitates servicing and also dispenses with separate pilot supply piping.

To install the unit, it is necessary only to connect the main air or oil supply to one end block, and lead the usual connexions to each power cylinder. For pneumatic service, protective hoods are fitted to the main exhaust ports in each end block, and also to the exhaust ports of any solenoid pilot mechanisms which may be incorporated. For hydraulic service, the user must provide one drain line only back to the pump reservoir, solenoid drains being fitted integrally in each valve element.

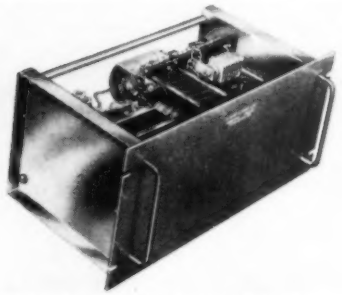
To give an idea of the ultimate economy which can be realised by this system of construction, in the case of a 12-point double solenoid operated hydraulic unit the total number of interconnecting pipes is reduced from 84 to 2! namely a supply and a drain connexion from the pumping set.

At the present time, these packaged units are available in the $\frac{1}{2}$ in. bore 4-way pattern only. The cost of the unit itself compares favourably with the total cost of a corresponding number of conventional valves, even in those cases where a smaller bore size would suffice for some of the points. It should also be emphasized that any desired mixture of operating mechanisms can be provided in a bank. If any of the points are required for 3-way working only, the unused cylinder connexion is plugged.

Baldwin Instrument Co Ltd
Brooklands Works
Dartford, Kent

Mains stabilizer now rack-mounted

Recently added to Claude Lyons' range of cabinet-mounted a.c. mains stabilisers is a parallel range of similar units for mounting in the standard Post Office 19 in. relay rack. Two series are available: the BMVR unit in which the correction rate is 1 volt per second, and the TCVR stabiliser which corrects at 40 volts per second. With an output accuracy of ± 0·5 pct, effects of load, frequency (47-65 cps) and power are stated to be nil. For both series, outputs of 7, 8, 9 and 12 amps and 32, 40 and 53 amps are available. Stabilisers can be had for input voltages between 200 and 250, also for 100-127V. Special types with voltage variable by panel control are also available.



Claimed to be the fastest distortionless voltage regulator made

Claude Lyons Ltd
Ware Rd,
Hoddesdon, Herts

TV assists internal pipe welding

A new Quasi-Arc internal welding boom for welding internal longitudinal seams in small-diameter pipes, incorporates TV equipment for guiding the welding head. The equipment can be used for pipes up to 28 ft. in length, and consists of a tubular steel boom, fitted to a fabricated steel support structure. The boom has 6 in. vertical adjustment by means of a hand-wheel-operated lead screw to cover various plate thicknesses and the height of the bottom of the pipe from ground level.

A Unionmelt D.S.H. welding head, suitable for parallel electrode welding, is fixed to the end of the boom, and an angle control sector is provided for positioning the electrode in relation to the seam. A continuously rated melt recovery unit is incorporated for reclaiming unfused powder. Near the welding nozzle at the end of the boom is a television camera and a 150-watt photoflood lamp, on a universal type mounting bracket. The camera provides a picture of the welding nozzle pointer in relation to the seam. If the pointer moves off the seam, adjustment can be made to bring it back, thereby ensuring that the weld is deposited in the correct place.

A special hopper of 50 lb capacity is supplied for the carrying of Unionmelt flux. During welding, the end of the boom is suported by twin spherical support rolls, which ride on the inside of the pipe and ensure maximum rigidity at the welding point. Twin 150 lb wire reels are fixed to the support structure at the end of the boom.

The operator's control desk comprises camera control unit, 14 in. monitor and control panel for the welding head and roller beds—all mounted in a sheet metal casing.

Quasi-Arc Ltd
Bilston
Staffs

Two new electrode holders

For work in tight corners the J.H.2. holder can take $\frac{5}{32}$ in. electrodes

Following their successful introduction from America of the well-known Jackson A.3.S. electrode holder, Lincoln Electric have now commenced full scale manufacture of two smaller models, the A.W. and J.H.2. Both electrode holders have crown channel type jaws of 98 pct copper alloy, and are thoroughly insulated, with full protection from accidental arcing. The jaws have fibre-glass reinforced plastic insulators for greater heat resistance and durability, with specially designed handles to give greater ventilation and operator comfort.

Type A.W. is a medium class holder for currents up to 300 amps. With a weight of 14 ozs. (length 9¾ in.) it is one of the lightest holders made to take $\frac{1}{4}$ in. electrodes. The J.H.2. holder is rated for 200 amps and will handle $\frac{5}{32}$ in. electrodes. With its low weight of 9½ ozs. (8 in. long) and streamlined construction, the J.H.2. is especially recommended for work in difficult places and for reducing operator fatigue.

Lincoln Electric Co Ltd
Welwyn Garden City
Herts

Pulse height recorder

A new scanning unit—the type 701—has recently been introduced by Isotope Developments. It employs a strip-chart recorder for automatic plotting of pulse height spectra, in conjunction with scintillation counting equipment incorporating a single channel pulse analyser and a ratemeter. The recorder drum is direct-coupled to a 355° potentiometer which varies the discriminating voltage of the pulse analyser, while the pen movement (controlled by the ratemeter) follows the corresponding pulse rate. The scanning time can be switched to 10 minutes or one hour, and the chart length per scan is 6 inches. Each 6-inch record represents a scan over either the complete voltage range or the upper half of the voltage range, as selected by a 2-position switch.

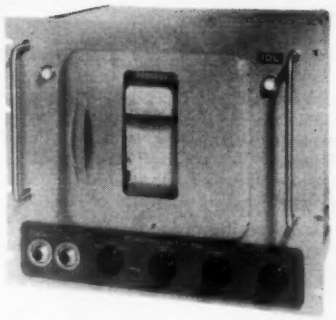
The servo-type precision 10K potentiometer has a linear accuracy of ±0·5 pct.

Calibration marks can be put on the chart at any required point by means of a switch which makes the recorder read full scale or zero. The exact zero of the potentiometer is indicated by means of a 'witness' mark. According to the position selected on one of the switches provided, the instrument will either stop after a single scan or will scan repetitively. In either case a light gives warning of completion of each scan. Repetitive scanning is useful for studying the drift of characteristics with time.

Another switch permits the upper half of the normal scan to be separately expanded into a full 6-inch record, thus giving the equivalent of a 12-inch chart length per full scan. Pre-set potentiometers are provided for accurately defining the voltage scanned.

The instrument is designed for standard Post Office rack mounting with dust cover (front panel size 15$\frac{11}{16}$ in. × 19 in.), but is also suitable for bench use. Special practical features of the design include an unspillable inkwell for the recorder, and quick-drying ink which does not smudge or grow mould. Mains input plugs at the rear permit connexion to existing equipment without the need for an extra mains supply point. The lightweight door swings completely clear or can be quickly removed to give easy access. A paper tear-off device is fitted, but the chart can hang freely through a slot in the bottom of the door, or can be wound on to a take-up spool.

Isotope Developments Ltd
Beenham Grange
Aldermaston Wharf
Reading, Bucks



Plots automatically pulse height spectra from a single channel analyser

Wet deduster for graphite work

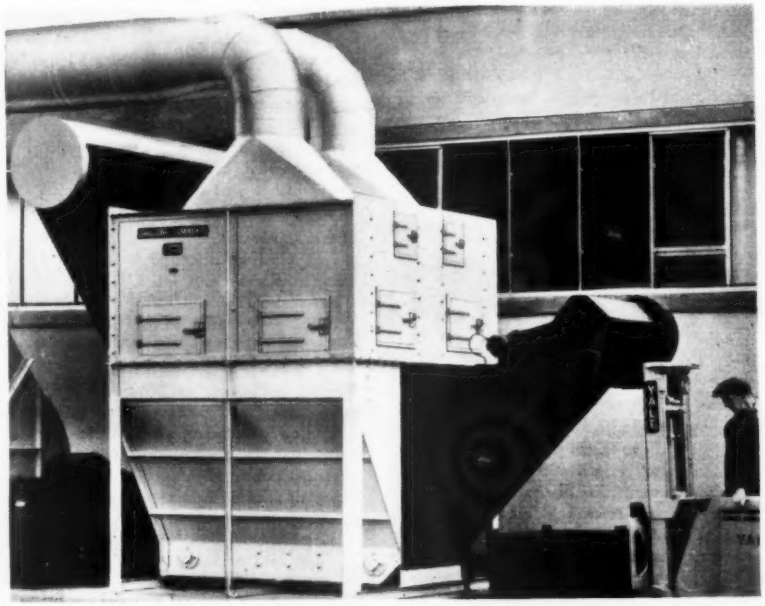
Recent Parliamentary legislation in the field of airborne dust pollution calling for higher standards of dust control and more efficient dust collection, has revealed the need for a wet collector of improved design suitable for the widest field of application in both light and heavy industries.

Numerous advantages can be obtained from a properly designed self-induced spray type wet deduster, such as a constant resistance to air flow, no secondary dust disposal hazard, low space requirements, a high collection efficiency independent of unit size and absence of fire hazard.

After an exhaustive study of desirable operating characteristics, with particular reference to low maintenance costs, Dallow Lambert have produced a new range of self-induced spray type wet dedusters —series MG—which are now available in 13 standard sizes ranging from 2,000 c.f.m.–48,000 c.f.m. capacity. The deduster, which has been critically tested in the company's laboratories followed by extensive site evaluation, is available with four principal methods of sludge removal: mechanical, gravity, manual or hydraulic.

No pumps, nozzles, high speed rollers or other mechanical spray producing equipment is employed, so avoiding wear and chokage normally associated with such equipment when dealing with sludge or slurries. Considerable attention has been devoted to the provision of automatic controls to ensure optimum operating efficiency under all conditions and to reduce water consumption to a minimum. The new plant is expected to find application in graphite manufacture and in gas clean-up systems.

Dallow Lambert & Co Ltd,
Thurmaston,
Leicester



One type has mechanical sludge removal by drag link conveyor

Radiation checks for Shippingport PWR

The monitoring system for the PWR plant at Shippingport, Pennsylvania, designed and built by the X-ray Division of Westinghouse Electric Corporation, will have the following responsibilities:

1. Check for leakage in the reactor's water cooling system
2. Check the radiation accumulation in the boiler compartments, to make sure that the areas are safe to enter for maintenance during shutdowns
3. Check for contamination in the ventilating and cooling air
4. Keep a continuous chart record of radiation in the various areas of the plant

If radiation levels in the selected areas exceed the preset limits, alarms will be actuated by contact meter-relays, furnished by Assembly Products, Inc., Chesterland, Ohio. If contamination is detected in the air systems being monitored, the meter-relays will also actuate solenoids. These in turn will operate butterfly valves to stop the circulation of air.

To ensure precise monitoring of radiation at lower levels, and at the same time provide for a wide range, the dials of the meter-relays have three-decade logarithmic scales, instead of linear ones. Detectors used include GM tubes, ionization chambers, and particle detectors.

Like all the equipment used in the monitoring system, the meter-relays were specified because of their reliability and maintenance-free operation. They also offered a means of combining a con-

stant visual indication of prevailing radio-activity with easily adjusted preset limits of radiation. The principal alternatives, passed over primarily because of their bulkiness and greater complexity, would have been ordinary panel meters hooked up to electronic alarm circuits.

The radiation monitoring system is housed in the auxiliary control room at Shippingport. This centralized location will not only permit quick reading of radiation levels but will also simplify maintenance. The electronic circuitry for each of the eleven channels is mounted in the equipment racks on 'roll-out' type slides that allow immediate access. In the rear of each rack are large removable doors.

Basically, each channel in the system consists of a radiation detector which produces an electrical signal proportional to the activity present; an interconnecting cable that feeds the signal to a computer-indicator; and a computer-indicator that converts the signal into an intelligible meter indication. With only one exception, each channel includes a background flasher to indicate channel operation when the radiation level is insufficient to cause a meter deflection. A d.c. signal is provided to drive a strip chart recorder.

Kenneth Kiesel, Westinghouse project engineer, sets one of the contact meter-relays on the Shippingport monitoring equipment

Other features of the system include etched wiring and plug-in circuits wherever practical; uniformity of circuits to the greatest degree possible; tubeless power supplies, ruggedized tubes; and two low voltage and filament power supplies in each equipment rack, with either unit being capable of supplying the entire rack in an emergency.

Assembly Products Ltd,
Chesterland,
Ohio, USA

In brief

Constant speed of piston in one direction with free return is feature of new *Hydrocheck* unit recently introduced by Martonair Ltd, Parkshot, Richmond, Surrey, for their air cylinders. Intended for use with tool and drill feeds and turnover devices its characteristic control is maintained up to loads of 1000 lb.

Fully automatic programmed control for oil- or gas-burning installations with flame-failure feature is incorporated in new FSM4 unit from Elcontrol Ltd, 10 Wyndham Place, London W1. It uses an infra-red cell and an a.c. amplifier. At a price of only about £50, deliveries have started.

Two new oscilloscopes have been announced from Philips Electrical Ltd, Century House, Shaftesbury Avenue, London WC2. GM 5666 is a d.c. coupled model for l.f. investigations in mechanical, chemical, biological and medical fields. GM 5662 incorporates a wide-band 'Y' amplifier with a falling frequency characteristic and a versatile time-base. It is suitable for observation of pulse-type phenomena.

A wide variety of counting duties is undertaken by a new range of **electromagnetic batch counters** from Londex Ltd, 207 Anerley Rd, London SE20. Bulletin 174 from firm gives full details.

Prices for **semiconductor-grade silicon** were recently cut by 20 to 25 pct by Texas Instruments Inc, Dallas, Texas, USA, owing to improved production coupled with increased demand. New prices are: Standard grade $240, Premium grade $400, Research grade $750 —all per pound.

For low- and medium-pressure applications the *FREE-END* hose coupling has recently been introduced by Airtech Ltd, Haddenham, Bucks. No preparation of the hose end is required and a new joint can be made in ten seconds. A model in nylon is now available for up to 250 psi.

Silicone rubber tape—not sticky to the touch but self-adhesive to itself—is announced by Union Carbide International, 30 East 42nd St, New York 17, NY, USA. It is made from a new type of fusible silicone rubber developed by Union Carbide and one variety conducts electricity.

Midget oscilloscope—it weighs less than 8 lb and is only 10½ inches long—has been specially designed by Kelvin and Hughes Ltd, Livingstone College, Leyton, London E10. Its main use is for monitoring and tuning transmitters of KH echo sounders.

Designed for jobs where pneumatic and hydraulic hose lines have frequently to be fitted and renewed, a special **hosepipe assembly vice** has been marketed by Consolidated Pneumatic Tool Co Ltd, 232 Dawes Rd, London SW6. New connexions can be made in a moment, even with h.p. reinforced hydraulic hose.

After years of development testing Union Carbide International, 30 East 42nd St, New York 17, NY, USA, have introduced a **liquid nitrogen refrigerator** which can attain temperatures of minus 210°C. A single charge of liquid nitrogen is said to last about 23 days. One use is for shrink fitting small mechanical parts.

A compact control panel for their pneumatically-controlled valves has been introduced by Telektron (Great Britain) Ltd, 109 Jermyn St, London SW1. It provides high and low speed together with step-by-step adjustment and position indication.

Available in a new version — the P.W.7000 — is the **gas refrigerating machine** made by Philips Electrical Ltd, Century House, Shaftesbury Avenue, London WC2. The single cylinder unit can produce five litres of liquid air or nitrogen an hour and starts producing only 15 minutes after start-up. Gas is not compressed and it does not pass through any working parts—thus product is exceptionally pure.

No dust bag is feature of **industrial vacuum cleaners** by New Welbeck Ltd, Moulescoomb Way, Brighton 7, Sussex. This means performance is unaffected by amount collected. Three wheel-mounted models are made, together with a smaller one carried on the back.

Flanges produced by centrifugal spinning are quite as good as those made by conventional forging for many purposes according to tests recently carried out in the foundry of Firth-Vickers Stainless Steels Ltd, Sheffield. Delays waiting for forged flanges in the chemical, oil, nuclear and other industries can in many cases be eliminated by specifying centrispun flanges, the firm say.

Small laboratory samples of bulk powder material can readily be obtained by a new **cascade sample divider** recently announced by Pascall Engineering Co Ltd, Gatwick Rd, Crawley, Sussex. A rotating cone cascades the powder from a hopper into six receiving bins which receive the same distribution of particle sizes.

Detection of water in aircraft fuel to the tune of 5 parts in a million is claimed for a new instrument by Wayne Kerr Laboratories Ltd, Tolworth, Surrey. Principle is still held secret but the firm admit it uses a dipping electrode.

Recent application of standard BC4 electronic photocell decade **batch counter** by Electronic Machine Co Ltd, Mayday Rd, Thornton Heath, Surrey, is counting metal bottle caps coming from the manufacturing machine. Presetting and recording is available.

Portal radiation monitor for scanning personnel for gamma and hard beta radiation following radioactive contamination is now available from Nucleonic Corporation of America, 196 Degraw St, Brooklyn 31, New York. Designed to fit a conventional door opening, the unit incorporates separate visual and audible alarms that indicate the presence of contamination on the right or left side, head or feet of the person passing through the door.

Cross Section by GRACCHUS

BY THE TIME this appears we shall probably have been told all we are allowed to know for the present about 'taming the H-bomb.' What this will be I can only speculate but I assume it will confirm and amplify what has been common knowledge for some months: that Harwell scientists—and American ones too—have at last succeeded in producing genuine thermonuclear neutrons for appreciable periods of time in their laboratories. Doubtless too, we shall have received the customary warning not to get worked up about this and an assurance that any practical power-producing machine is years and years away. This constant playing down of thermonuclear power is getting somewhat monotonous. It has been shown many times that once a scientific principle has been proved and a pressing social or economic need demonstrated then the engineers and technicians can translate it into practical reality in a very short time. Both these conditions now exist in this country.

As a side issue to this thermonuclear business I think some credit is due to the science writers of the daily newspapers whose constant and cumulative nagging has undoubtedly done a lot to wring out of the authorities this great news. In saying this I am well aware of the sensational-looking stories that have appeared on 'H-power' from time to time during the past year, but I think if one can get below the headlines it will be found that most of them have now been confirmed as substantially true. It is not generally realized, I suppose, that a newspaper correspondent does not write headlines. They are done by a specialist whose job it is to make people read what follows—and they mostly do.

THE DEATHS of Lord Waverley and Lord Cherwell within six months of each other removed the two men who really got atomic energy going in this country. Leonard Bertin in his *Atom Harvest* relates how by mid-1941 Sir George Thomson's MAUD committee were able to recommend to Prime Minister Winston Churchill through Cherwell, his scientific adviser, that (a) a U-235 bomb could be made, and (b) power and plutonium could be produced in a heavy water reactor. In August Churchill wrote to the Chiefs of Staff his historic minute—'although personally I am quite content with the existing explosive I feel we must not stand in the way of development and I therefore think that action should be taken in the sense proposed by Lord Cherwell and that the Cabinet Minister responsible should be Sir John Anderson (later Lord Waverley).' Waverley set to on this task and 'Tube Alloys' was created. Before long however all work was transferred to America until the end of the war.

It is not always appreciated that Lord Waverley was a scientist in his younger days and got his BSc from Edinburgh in 1903. I remember him telling me one day about a year before his death that he believed he was one of the first men to work seriously on uranium—in Leipzig, in 1903, where he had gone to study under Ostwalt the new problem of radioactivity. It was not till nearly half a century later, he told me, that he began to appreciate what he'd been trying to do.

IN AN APPENDIX to the Fleck report on the AEA Industrial Group organization there are defined for all to see —*scientist, technologist* and *technician*. These things are notoriously difficult and unfair and the latest attempt really gets no-one anywhere. The compilers are obviously unsure as to whether a scientist is more U than a technologist, for in the preamble they refer to 'technical and scientific staff' whereas in the actual definitions the scientist is by implication a much brainier chap than the mere technologist. The scientist 'has a full scientific education, probably as far as a higher degree' but the technologist (clot!) only has a 'sound scientific background.' He, poor fellow 'is more concerned with the application of one branch of scientific knowledge than with the extension of the general fund of basic science' whereas the scientist combines 'the mastery of a specialized science with a general understanding of scientific thought and ideas.' Perhaps relenting after slaying the unfortunate technologist, they then go on to define him in terms of a 'professional engineer,' describing his work as 'predominantly intellectual' and requiring 'original thought and judgment.' In view of all this can a mere engineer, however brilliant and eminent, ever be called a scientist or must he always remain a sort of senior NCO? I'm sure this is not intended—and it doesn't happen in practice either.

Incidentally, the scientist 'is also a man who continues to practise his science so that he is able to keep abreast of new developments.' On this definition I wonder if Sir Alexander Fleck still likes to be called a scientist?—or Sir John Cockcroft too, for that matter?

WITH EASTER not so far away it seems a little peculiar to be harping back to Christmas, but on the appointed day for these things I was disposing of my collection of cards when I had a good look at the one from Accles and Pollock, the steel tube people. In '3-D,' this showed Mr A and Mr P dressed as a pair of Father Christmases riding in a curious sledge pulled by an even curiouser reindeer. Mr A (or is it Mr P?) is wielding a whip of very fine wire—at least I thought it was very fine wire. I now find, on closer examination that it is tube—seamless stainless steel ·006 in. o/d by ·001 in. i/d! At least that's what the card said, but I was not entirely convinced since my eyes are scarcely capable of discerning a 1 thou. hole. However a simple flattening test did indicate that it was a tube. I wonder what on earth they're used for —apart from Christmas cards.

RECENTLY I had the pleasure of hearing a talk by Dr H. Righi who is head of the Beckman Instrument concern which has branches in Germany and the U.S.A. Dr Righi was introducing a new type of infra-red gas analyser at Winston Electronics who are to handle them in this country. As an example of product control he instanced that excellent substance, Munich beer. It seems that in the spring they have a special brew and it has to be matured six months before it is served. To see whether it was fit for sale or not a quantity was poured over a bench which was then sat upon by men in leather breeks. There they sat for an hour or two, happily drinking beer. At the end of the period they tried to stand up—and if their breeks were not firmly stuck to the bench, then the beer was no good. The point of the story, as Righi said, is that it's no good waiting till the product is finished before testing it—it's too late then.

'RISLEY ACROBATS with a talent for fast footwork'—so runs a programme note on an act in this year's Bertram Mills circus at Olympia. It continues —'(the act) is remarkable because the most important individual who is "juggled" is a fully-grown girl of about twenty and the act is entirely novel too, for it is the first one we have seen in which a springboard is combined with Risley work!'

Oh, I don't know—some IG men have succeeded admirably in doing just that.

COMPANIES

BP will have linac

A 4MeV linear accelerator has been ordered by British Petroleum Ltd for their Sunbury-on-Thames research station. Believed to be the first machine of its kind in the country to be built specifically for industrial research in the petroleum and chemical industries, its design and construction is being carried out by Mullard Research Laboratories for the contractors, Philips Electrical. The Mullard linac, which was described in NUCLEAR POWER, December, p 497 will give high-energy electrons, deep-penetration X-rays or neutrons. Mean electron energy is 4·0 MeV, mean electron output 800 watts at 500 pps and pulse repetition frequency is variable between 100 and 500 pps. Maximum X-ray output using a tungsten target is 700 roentgen per minute at 1 metre from the target.

A special building with radiation protection features is being built at Sunbury. As the unit is portable and measures only 6 ft long, 2 ft 3 in. wide and 6 ft 3 in. high, design problems of this building are considerably simplified.

High purity niobium on US market

Niobium melting stock claimed to be of the highest purity ever made commercially available, has been pioneered by the Union Carbide Corp, New York. The metal is produced in the form of roundels, small cylindrical shapes, that are easy to handle and weigh. Ingots are produced by consumable electrode arc melting, the bar-shaped niobium electrode being prepared by compacting the easily compressible roundels. Purity of the stock is claimed to be 'significantly higher' than that specified for reactor grade. Its medium strength and high density at elevated temperatures make the metal potentially valuable as a base for high temperature alloys. Already in use in the nuclear industry—it is used in the Dounreay fuel elements (NUCLEAR POWER August 1957)—it may also have possibilities in the electronics field.

Reactor zirconium cheapest ever

High grade zirconium sponge is now available for immediate delivery at the lowest ever price according to Niles C. Bartholomew, vice president and general manager of The Carborundum Metals Company, Akron, New York. This latest price reduction lowers reactor grade zirconium to $7.50 per pound for 1,000 pound lots—approximately one-third of its 1953 price of $22 per pound. This is the third major price reduction of the metal announced by Carborundum in four years. Commercial grade is also reduced to $5 per pound—and both reductions are due to large volume and improved production efficiencies, say the company.

Carborundum has been supplying high grade zirconium for use in both AEC and privately-owned reactors. The Shippingport PWR, for example, uses zirconium made by the company and zirconium has been specified for use in boiling water, sodium cooled, homogeneous, fast breeder and pressurized water reactors. A pioneer producer of zirconium, Carborundum started production of the metal in 1953 at its Akron plant. In 1956, a new multi-million dollar plant was added at Parkersburg, West Virginia.

CJB open research station

To extend their activities in the chemical engineering and automatic control fields, Constructors John Brown Ltd has recently established a research and development station at Leatherhead, Surrey. Primary object will be to undertake sponsored development work on behalf of government departments and industrial organizations, and also for the engineering and construction divisions of CJB. It will cover process development and investigation of chemical engineering problems, development of automatic control systems and their application and special problems of nuclear engineering.

The new station has a site of four acres and is equipped with laboratories and pilot-plant buildings, and special attention has been given to facilities for development work requiring large-scale pilot-plants. So far the staff numbers 30 consisting of chemical engineers with experience in process development work, automatic control engineers, and supporting staff for chemical, physical, mathematical and design work.

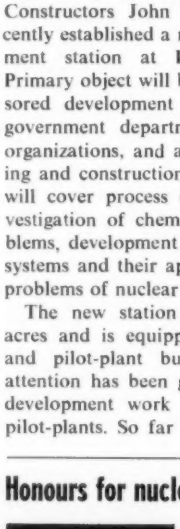
Ready-made sniffer gear

Prefabricated assemblies for the burst slug detection gear at Hunterston is being supplied by Accles and Pollock Ltd. Normal practice has been to build up the installation on site from straight tube, but prefabrication should not only save time and money on site, but simplify quality control. Complete assemblies will include over 40 miles of stainless steel tube, manipulated to the required shapes, welded and fitted with special couplings.

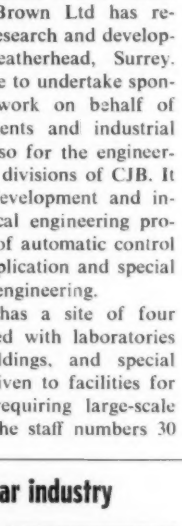
Airtech form engineering division

Well-known as contractors to the British and overseas governments, for whom they have carried out work on aircraft, missiles and specialized vehicles, generally in the electronic and hydraulic field, Airtech Ltd have now formed an engineering division. In addition to offering a consultant design service for complete hydraulic and pneumatic systems, the company is manufacturing a range of these components for industry at home and overseas. In conjunction with the marketing plans for their own range of products, Airtech will be pleased to hear from manufacturers of industrial equipment who wish to expand the sales of their products at home and overseas, generally to the wide field of industry using hydraulics and pneumatics.

Honours for nuclear industry

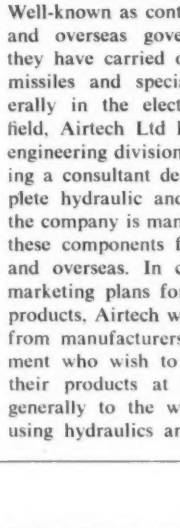


WORBOYS

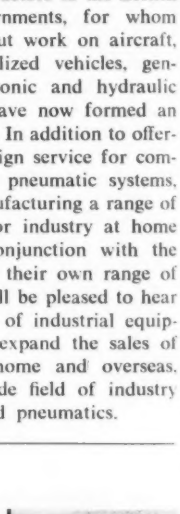


WARD

Knighthoods



METCALFE



BALL

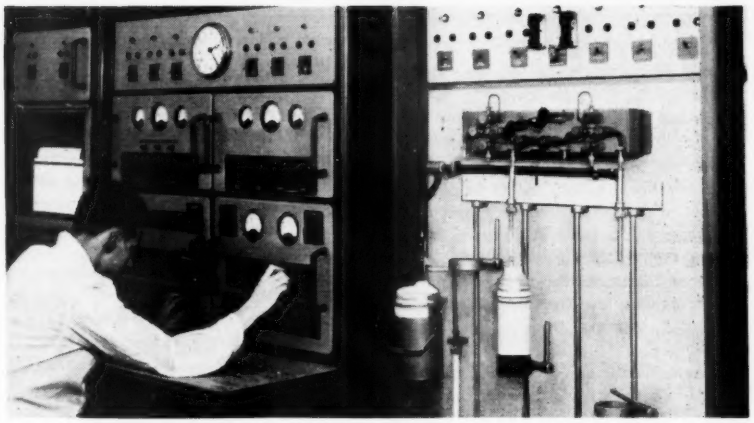
CBE's

The New Year's Honours List once again includes several members of the nuclear industry. Among the knighthoods are Dr. Ashley Ward, president of Thomas W. Ward Ltd, Walter Worboys, ICI director, and Foster Robinson, chairman of Teleflex Products. CBE's go to Eric Ball, managing director of BTH and director of AEI, Clifford Metcalfe, managing director of EMI Electronics, and Sir Hugh Stobart Chance, deputy chairman, Chance Bros. Director of Morgan Crucible, Brig George Walton, and Neville Gass, chairman of BP are awarded the KBE. Listed among the MBE's are J. K. Lightfoot, works superintendent of English Electric, Stafford, G. McG. Perry, assistant manager of the electrical department of Harland and Wolff Ltd, J. Rutherford, foundry man at William Beardmore and Co Ltd and J. O. C. Whelans of Mullard Radio Valve Co Ltd.

Hex analysis at Dounreay

Mass spectrometry and vacuum furnace equipment has been supplied for Dounreay by Metropolitan-Vickers Electrical Co Ltd. This includes a type MS2 mass spectrometer for isotopic analysis of heavy metal halides such as uranium hexafluoride. Basically similar to a standard general purpose machine, a special gas handling system and ion source have been incorporated because of the corrosive properties of the vapour. Also in use at the moment is standard machine (type MS 3) for routine gas analysis, and during this year another (type MS 5) will be delivered for rapid determination of the isotope ratio of solid samples using the surface ionization technique.

High frequency vacuum induction furnaces supplied are for casting uranium and uranium alloys. In operation now, the installation covers nine furnaces supplied from three 25 KW motor generator sets together with control cubicles, capacitors and selector switches. Melting is performed in graphite crucibles under high vacuum and all operations carried out in glove boxes. Inductor coils are water-cooled and protected by water-flow relays; if the water supply falls below the minimum requirements, visual and audible warning systems come into operation and the h.f. supply automatically switches off. This protective system is also brought into operation by vacuum failure. Furnace and generator switches are in control cubicles enabling the operator to switch to any furnace and take supply from any generator; any three furnaces can be operated at a time. Operators are protected from live contacts by electrical and mechanical interlocks which are designed to ensure the correct sequence of operations.

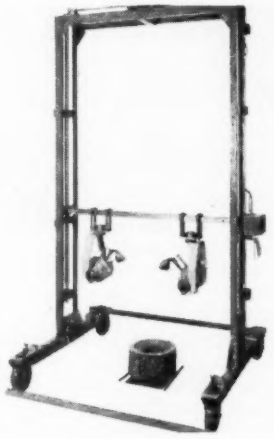


Metro-Vick mass spectrometer of this type is in use at Dounreay for isotopic analysis of uranium hexafluoride and other heavy metal halides

3 D flaw detection

Recently arrived in Yugoslavia is a heavy duty stereo-gamma-radiographic unit capable of using two cobalt 60 sources of 700 millicuries for determining flaw depths in heavy castings. Marketed by Nuclear Research Applications Ltd, this *Emefco* (type M2/51) equipment uses twin Gamma-rays machines (type ASS/51) and takes twin stereographs on a single film. With a free span of 1m and a free height of 2m, the unit can be wheeled over large castings. Operation is manual for setting of angles and distance between isotopes, and electric for height by means of twin square thread lifting screws. Full referencing is possible through engraved scales giving distance between isotopes and all angles in space.

Another gamma-radiography unit using a single 300 millicurie cobalt 60 source has been sent to Formosa for use by the Central Trust of China. This consists of a Gamma-rays ASS/49 machine and a full set of *Emefco* radiation control instruments and accessories, together with the source container. The first British isotope to be shipped to Formosa, it was supplied by M. Falk and Co Ltd.



Stereo-radiographs for flaw depth determination in heavy castings are taken with this equipment using twin cobalt 60 sources

In brief

Two standard Birlec adsorption driers have been ordered by Sunvic Controls to provide dry air to control instruments at Berkeley. Nuclear Power Plant Co have ordered a Birlec unit to dry compressed air for testing reactor vessels at Bradwell.

Over sixty factories from ten countries will take part in the International Instrument Show at Caxton Hall during the last week of March. Products shown will include latest advances in fields of printed circuits, UV-TV microscopy, e.p.r. spectroscopy and telemetry. Admission is free—tickets from sponsors, B & K Laboratories Ltd, 57 Union St, London, SE1.

London office of Pulsometer Engineering Co Ltd, has been moved to Pulsometer House, 20-26 Lamb's Conduit St, London, WC1 (tel : Holborn 1402).

New liquid oxygen producing plant being built at Crawley by British Oxygen Gases Ltd, will also produce liquid nitrogen and argon. Work on site has already begun and plant should be in production in 1959.

Permanent European office has been opened by Atomics International at 29 rue de la Coulouvrenière, Geneva.

Ketay Ltd, in conjunction with Norden-Ketay Corporation in the US, has recently concluded a licensing agreement with the Société Anonyme Précilec of France. This provides for the manufacture and sale of Ketay and Norden-Ketay synchro- and servo-mechanisms in France, together with the interchange of technical and manufacturing information between the three companies.

Southern Areas Electric Corporation Ltd announces acquisition of whole of share capital of Designs and Installations Ltd. Managing director J. W. C. Milligan states this is part of Southern Areas policy of expansion in nuclear energy, electrical, electronics and precision mechanical engineering fields.

Hartley-Ward Films Ltd recently became the first industrial films production company to be elected to the membership of the FBI.

Siemens Edison Swan Ltd, at their new factory in Tottenham, are now equipped to coat with p.t.f.e. dispersion articles of all sizes. Newly installed plant includes sintering ovens capable of accepting parts equivalent in size to a double-decker bus, and conveyer ovens will handle large quantities of small parts.

INSTITUTIONS

WPC in Montreal

Theme of the sectional meeting of the World Power Conference to be held in Montreal from September 7–11, 1958 will be:

Economic trends in the production, transportation and utilization of fuel and energy.

Arrangements have been made by the papers committee, of which Sir Josiah Eccles is chairman, for sixteen papers to be presented by the British national committee. Among these will be six on nuclear topics:

Economics and design of the pumped storage scheme at Blaenau Ffestiniog by E. S. Booth (CEA) and Geoffrey Kennedy (Kennedy and Donkin); *Economic integration of coal-fired, nuclear and hydraulic generation of electricity with special reference to Scotland* by J. Henderson (SSEB) and C. L. C. Allan (North of Scotland Hydroelectric Board); *Trends in the financing of power development* by *Charles L. Blackburn* (Merz and McLellan); *Economics of nuclear fuels* by J. A. Jukes (UKAEA); *Review of the future of nuclear reactor systems in the light of the available research and operating experience* by Sir Christopher Hinton; *Trends in the design of large British nuclear power stations* by H. West (AEI-John Thompson).

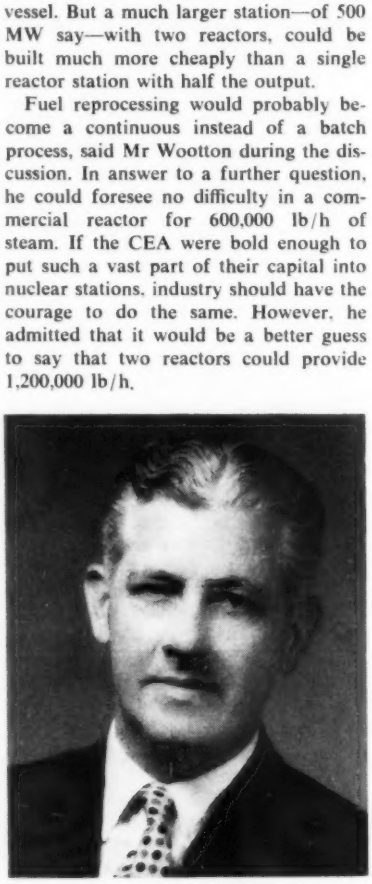
Supplies of the general programme, with membership and other application forms, are available from the British National Committee at 201 Grand Buildings, Trafalgar Square, London, WC2.

Calders for process steam

Versatility of the gas-cooled reactor as a means for producing steam for process use was stressed by W. R. Wootton, assistant manager of Babcock and Wilcox atomic energy department, at a recent meeting of the Combustion Engineering Association. The dual pressure steam cycle enabled a considerable fraction of the total steam production to be at high pressure—perhaps 30 pct at 2000 psi. But demands of less than 500,000 lb/h from a single source would probably prove uneconomic. For marine work, 1 pct enrichment would reduce the size of a 30 MW plant from 7500 to 2500 cu ft.

Thermal efficiency of a very large plant would be appreciably lower than for one half its size because of the higher coolant pressure possible with a smaller reactor vessel. Mr Wootton quoted figures of 27 pct station net efficiency for a 1000 MW reactor and 29 pct for one of 500 MW. The smallest power reactor for outputs around 30 eMW might have coolant pressures of 250 psi in a cylindrical vessel; figure for the largest, about 300 eMW, might be up to 200 psi in a spherical vessel. But a much larger station—of 500 MW say—with two reactors, could be built much more cheaply than a single reactor station with half the output.

Fuel reprocessing would probably become a continuous instead of a batch process, said Mr Wootton during the discussion. In answer to a further question, he could foresee no difficulty in a commercial reactor for 600,000 lb/h of steam. If the CEA were bold enough to put such a vast part of their capital into nuclear stations, industry should have the courage to do the same. However, he admitted that it would be a better guess to say that two reactors could provide 1,200,000 lb/h.



W. R. WOOTTON
Versatility, efficiency, economy

Teamwork in Europe

Our experience of inter-governmental scientific organizations in the past has shown us that they can be very wasteful of our scarce scientific resources and that far too often they produce paper rather than scientific results. Very great wisdom and creative scientific leadership is required if they are to bear worthwhile fruit. This opinion was expressed by Sir John Cockcroft, speaking in Amsterdam late last year to the Fondation Européenne de la Culture. In a paper called *European collaboration in science*, Sir John reviewed the history of scientific teamwork in Europe, starting as long ago as 1813 with the visits to France of Sir Humphry Davy and his assistant Michael Faraday, and surveyed modern efforts in collaboration. In Switzerland, for instance, the CERN proton synchrotron is under construction by a team of 180 scientists, engineers and technicians drawn from 12 European countries. This team has been working together for four years and has 'built up a way of working which is a fine example of international collaboration.' The group leader comes from Britain, the chief radio expert from Germany, a Norwegian engineer played a great part in the first phase of the design, the structural work is being designed by a Swiss architect.

International organizations of this kind are not free from potential difficulties: there is always a danger that politics and national prestige will influence appointments and policy. But, Sir John believes, this has been avoided in CERN. Inter-governmental finance can also be a problem, but so far governments have appreciated the need for giving CERN a fair wind—and, Sir John went on 'we hope that they will continue to do so though the wind is a little chilly at the moment.'

Sir John emphasized the need to increase support for basic research in Western Europe. 'Already 25 pct of British scientists who go to North America with fellowships remain there,' he said. 'This drain of the cream of our young scientists will increase unless we make it attractive to them to return home.' Young scientists were more attracted, he believes, by good facilities and leadership than by salary levels, and we must therefore improve our research facilities, especially those of our outstanding leaders. And this means more funds for Fellowships to be held in Europe.

Designing pressure vessel joints

An analysis of the stress distribution in bolted flanged joints of pressure vessels and a design procedure based on it were given in a paper by G. F. Lake and G. Boyd of the Engineering Research department, ICI, just published by the Institution of Mechanical Engineers. Existing bases of design are considered by the authors to be unsatisfactory in that they are derived from treatments which assume elastic conditions to apply, and so lead to fictitiously high stresses. These stresses imply that parts of the joint assembly yield plastically, and this analysis takes account of such plastic behaviour.

Design procedure includes methods for determining the critical dimensions of a joint, including the number and size of bolts. The authors show that there is an approximate limit of 25,000 on the product of design pressure (psi) and inside diameter of flange (inches) within which it is possible to design flanged joints with flat gaskets. They derive a formula whereby a preliminary estimate of the flange thickness may be readily obtained. Other formulæ are given which enable closer approximations to be made of the

thickness required depending on the extent of the influence of plastic strain, and the design procedure is illustrated by examples.

Safety by colours

A new attack on industrial accidents is heralded by the publication on November 29 of a British Standards on *Safety colours in industry* (BS2929). Purpose of the recommendations is to establish throughout industry the use of a universal system of colours for the identification of hazards and safety equipment. The new system is in substantial agreement with the code of safety colours shortly to be recommended for world-wide adoption by the International Organization for Standardization.

Colours of the BS code are: red, meaning stop; orange-yellow, meaning warning of danger; green, used to identify or locate safety equipment and safety routes. Contrasting colours are used with the three main colours to form patterns which make for easier visibility. Geometrical forms may be used as part of a safety message, but their colour and meaning will always be the same.

Through a glass darkly

It is probably in the field of nuclear and theoretical physics that the most significant advances were made in 1957. Reviewing the year's scientific developments at his installation as the new president of the British Association, this was emphasized by Sir Alexander Fleck. The award of the Nobel Prize for physics to Yang and Lee for their work on parity conservation had called attention to the importance of constantly questioning the validity of our beliefs about natural phenomena, even when they have acquired sufficient respectability to be called 'laws.' Parity is concerned with the kinematics of groups of fundamental particles, and its universal conservation in nuclear transformations was assumed until disproved early in 1957 at the National Bureau of Standards and at Columbia University. 'Of more far-reaching significance, however,' said Sir Alexander, 'is the brief announcement that Dr Thonemann's team at Harwell have apparently succeeded in conducting a controlled thermonuclear fusion.' He went on, 'This is a piece of pioneer work the implications of which we can now only see darkly, but in the lifetime of some of us we may see them face to face.'

Management needs engineers

Engineers cannot shrug off responsibility for failure in industrial and political management. Since industrial civilization is largely the result of engineers' work and invention, it is for them to play a more active part in solving the problems of management and organization, according to Sir Ewart Smith speaking at the Institution of Civil Engineers on December 17. Vice-chairman of ICI and himself an engineer, Sir Ewart was giving the Graham Clark lecture on 'The engineer and management' to members of the Institutions of Civil, Mechanical and Electrical Engineers. Technical progress during the last two centuries, and particularly during the last fifty years, has been much faster than advance in managerial ability. Although management methods do not lend themselves to true scientific analysis, Sir Ewart believed that three principles basic in design engineering—his own field—could

SIR EWART SMITH
Simplicity, symmetry, continuity

be applied: simplicity, symmetry or balance, and continuity. 'In management,' he said, 'it is a matter of experience that a good organizational structure is usually one which is simple in form, balanced in its proportions, and clear in its lines of responsibility.' Though it will always in part be an art, management needs to be developed as a science, and the need is for more research, better analysis and, above all, for better teaching.

In the long term, the health and progress of any organization depends primarily on the quality of its leadership. A main responsibility of management should therefore be to train potential successors from the early years of service. This means giving trainees a wide variety of experience at the beginning of their career—this will help to find those with organizing ability and also be useful to the men who go on to specialize.

One of the reasons why engineers are not making a greater contribution to top management in all spheres, believes Sir Ewart, is that the desperate shortage of technologists confines most of them to specialist jobs. Study of the engineer's contribution in the field of management shows that 40 pct of companies in the engineering industry have boards with no technically qualified member, that of all directors of engineering companies, less than 22 pct had technical qualifications and that of these only three quarters were engineers. In general industry the position is, of course, far worse, and looking still wider—at Parliament—it is rare to find even one qualified engineer in a ministerial post.

Nuclear course at Birmingham

The intensive development of nuclear power in the UK makes demands on the various institutions of advanced education to provide suitable training courses. As a start, Birmingham University began in 1956 a year's post-graduate course—leading to a MSc by examination—in reactor physics and technology. For the first year the course had ten students and was subsequently expanded to about twenty. Aim of the course is to give a good training in the fundamental ideas behind the various reactor types. It is arranged to accept fresh graduates and those in industry, and introductory lectures and tutorial classes provided bring entrants to the necessary standard in the relevant branches of physics and engineering. Broadly, the syllabus covers nuclear, reactor and health physics, transmission of heat, reactor engineering, metallurgy, radiation chemistry, chemical engineering, geology, and electrical engineering and electronics.

Condition of entry is a degree in pure or applied science—normally physics, metallurgy, mechanical engineering or chemical engineering—and the fee is £81. Application should be made as early as possible to the Registrar of the University, Edgbaston, Birmingham 15.

In brief

Physical Society's 42nd Exhibition will be held at the Royal Horticultural Society's old and new halls from March 24 to 27. This year NUCLEAR POWER has been invited to exhibit for the first time.

A group of the British Conference on Automation and Computation — the Group for Computation and Automatic Control—was formally constituted on December 20. Chairman elected was T. E. Goldup, president of the IEE, and J. F. Coales (SIT) and E. M. Renals (ICWA) are vice-chairmen.

SIMA Convention for 1958 will be at Harrogate from November 6-9. Chairman of organizing committee is P. J. Ellis of R. B. Pullin & Co Ltd, Hon. Treasurer of the Association.

BOOKS

An authoritative text

Nuclear Chemical Engineering M. Benedict and T. H. Pigford. London 1957: McGraw Hill. 594 pp. Price 71s 6d

Professor Benedict's international standing as a chemical engineer and the leading role he has played in the development of the American gaseous diffusion process for concentrating U-235, make him singularly well qualified for preparing an authoritative text-book on the chemical engineering aspects of atomic energy. He is ably supported in this by Professor Pigford, at one time Director of the Massachusetts Institute of Technology School of Engineering at Oak Ridge and later Senior Development Engineer at ORNL. They have expanded their MIT and Oak Ridge lecture notes to produce a book dealing with 'the materials of importance in nuclear reactors and the novel processes which have been developed to concentrate, purify and separate these materials.' While most of the subject matter has been published before, no other single volume covers so authoritatively or completely the aspects of atomic energy of particular interest to the chemical engineer. This wide scope accounts for both the value and the limitations of the volume. The specialist worker will sometimes require more detailed treatment of his particular field but the average chemical engineer employed in atomic energy, wishing to obtain an insight into the processes used in the industry, will be more than satisfied with the depth of treatment.

Throughout the book, the theoretical treatment is authoritative, the authors having concentrated on basic scientific principles rather than engineering design details. Equipment, when discussed, is dealt with in a rather superficial manner and is not as up-to-date as one would have hoped. For example, when discussing solvent extraction equipment, American work alone is mentioned, no reference being made to the very considerable work published by Pratt, Thornton and co-workers. The balance of space devoted to various subjects can at times be criticized. For example, oxidation potentials and rates of oxidation are allocated eleven pages, whereas shielding, criticality and the toxicity of plutonium (and beryllium), all of which greatly influence the design of plants, are barely mentioned.

Anyone requiring an authoritative work dealing with the basic chemical and physical principles behind most of the processes used in atomic energy could not do better than obtain this book. Information on plants and equipment, rather than processes, and on the peculiar features governing their design will not be found here and for this, as far as it exists at all, there is as yet no escape from a laborious search through widely scattered literature. Many people newly entering the nuclear field will find this book of great value. Even if it does not deal with plant design, it will help plant operators and designers as well as research staff to a sound understanding of the scientific principles behind many of the atomic energy plants.

C. M. Nicholls

The Geneva reactors

Nuclear Power Reactors James K. Pickard (Geneva Series on the peaceful uses of atomic energy, J. G. Beckerley, Gen. Ed.) 388 pp. London 1957: D. Van Nostrand. Price 64s

While 'atom men' all over the world are already laboriously writing their contributions to the 1958 Geneva Conference, the curious cottage industry of boiling down the proceedings of the fabulous 1955 scientific beanfeast into readily-digested morsels continues—to judge from this, the latest effort in that direction. What a task it has been! As one who has done a little in this way himself I know something of the problem involved—or I should have said 'knew,' for I had done my boiling by the end of 1955 and time has by now healed the scars.

The latest contributor to this pool of knowledge, James K. Pickard, was with the U.S. Atomic Energy Commission's Division of Reactor Development before forming his own firm of consultants and therefore clearly knows his stuff. In his *Nuclear Power Reactors* he does what is required well enough within his terms of reference, but one wonders if it was really worth while, published at this late date. The 1955 Geneva Conference was an historic event which no one present will ever forget and while many of the papers on fundamental subjects are likely to remain as essential source material for years to come, it must be faced that the papers on power reactors are now largely of historical interest only and descriptions of these are readily available in Vol 3 of the Proceedings. Not that Mr Pickard confines himself to Vol 3: he runs through the whole gamut, but of necessity the bulk of his material is from the power reactor volume.

The trouble about the late appearance of the book is that many of the reactors he deals with are described as they were in the project stage whereas they are now working and are inevitably rather different from the Geneva description. Others which were only design studies then are still in the same condition now and unlikely ever to be built. However, if a concise record and reference of what went on in the power engineering side of the business at 1955 Geneva is required, this book should fill the bill.

What a wonderful thing it would be if Mr Pickard would produce a similar book on the 1958 Conference in say August giving us all we want to know about the papers *before* they are read. Now that would really be something!

W.D.

A basic treatment

Radiation Shielding B. T. Price, C. C. Horton and J. Spinney. London 1957: Pergamon Press. 350 pp. Price 60s

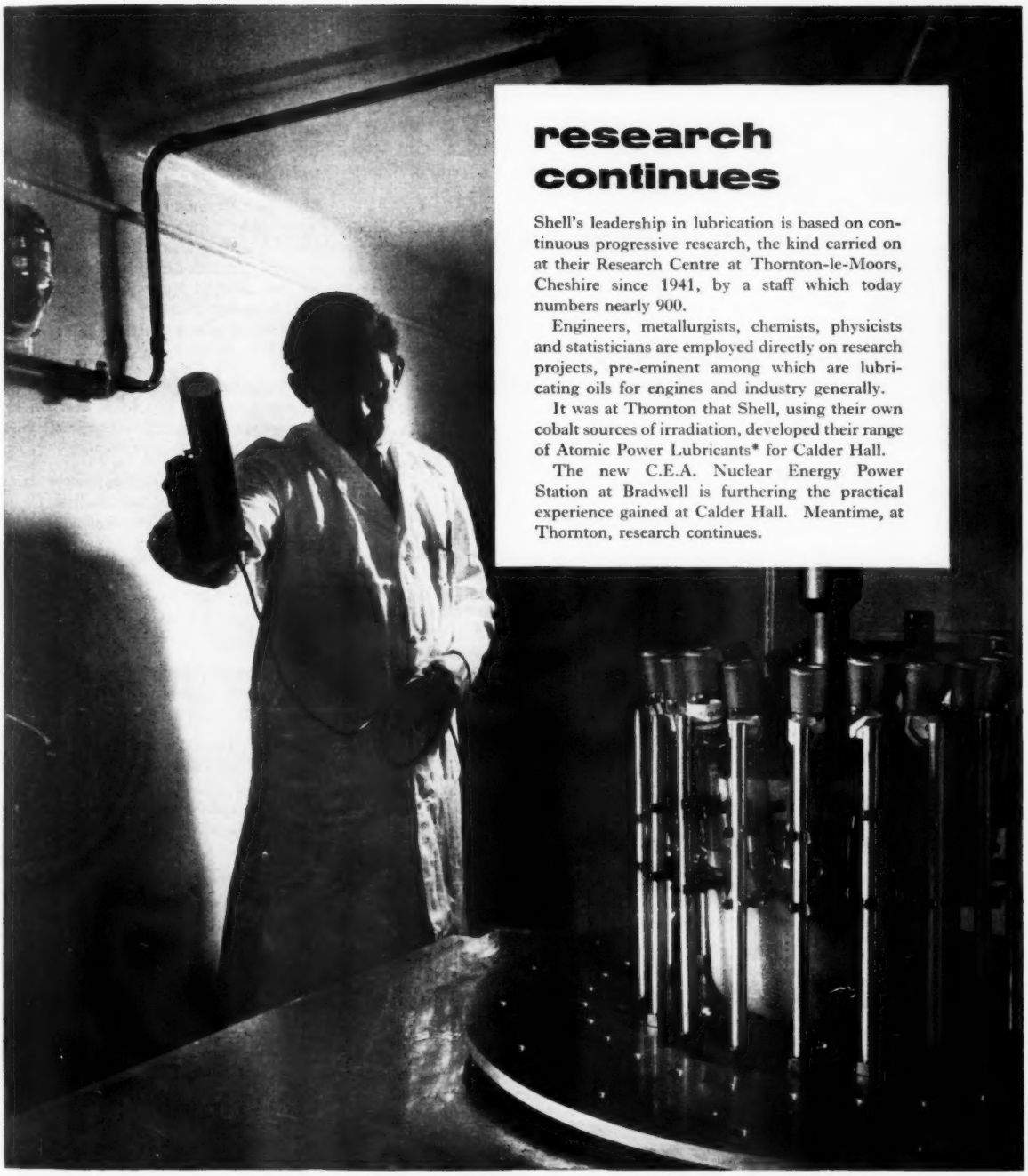
The aim of the authors in this book has been to lay down the fundamental principles of shielding against neutrons and radiation and not to produce a manual on how to design shields for specific purposes. Consequently, much of the book is devoted to discussions of the basic physics of the interactions of gamma-rays, electrons, and neutrons with matter. Actually, a large amount of data is included which is required for shield design, but it must not be supposed that it is a simple matter in general, readily to design a specific shield with the use of this book.

However, the prime aim of the book is to explain the physical processes important in shield design and in doing this the authors have given a clear and comprehensive account.

The general problems of reactor and radioactive materials are treated in the final chapter. One inevitable consequence of gamma-ray and neutron attenuation by a shield is that the shield becomes heated and so it is essential to know the consequent temperature distribution in the shield. Because of this the use of a thermal shield as a method of reducing the heating of the main shield is discussed. Next the general properties of shield materials are given with particular reference to concrete, and finally a few specific problems are considered.

Taken in all this is an excellent book, particularly for those who are interested in the fundamental physics of shield design. It is a pity, particularly because it does contain so much basic information, that the price has to be so high.

J. F. Hill



research continues

Shell's leadership in lubrication is based on continuous progressive research, the kind carried on at their Research Centre at Thornton-le-Moors, Cheshire since 1941, by a staff which today numbers nearly 900.

Engineers, metallurgists, chemists, physicists and statisticians are employed directly on research projects, pre-eminent among which are lubricating oils for engines and industry generally.

It was at Thornton that Shell, using their own cobalt sources of irradiation, developed their range of Atomic Power Lubricants* for Calder Hall.

The new C.E.A. Nuclear Energy Power Station at Bradwell is furthering the practical experience gained at Calder Hall. Meantime, at Thornton, research continues.

SHELL

* **The Shell A.P.L. range is further proof of Leadership in Lubrication.**

NAMES IN THE NEWS

Air Vice-Marshal SPENCER

H. DESMOND CARTER

A. H. HIRD

A. R. MATHIAS

Air Vice-Marshal G. M. C. Spencer, CB, CBE has been appointed to the technical liaison staff of William Jessop & Sons Ltd. He will be particularly concerned with titanium and vacuum melted steels and their uses in the aircraft and associated industries.

The Rt Hon Antony Head, CBE, MC, MP has been elected a director of Associated Electrical Industries Ltd.

G. & J. Weir Ltd have appointed **Dr R. S. Silver** as general manager of their technical division. Dr Silver is well known for his work in the fields of steam and combustion engineering.

The Penco Export Co Ltd, newly formed subsidiary of Pena Industries Ltd have appointed **Mr E. G. Lennard** as their managing director.

New chairman of the Lead Development Association is **Mr A. R. Mathias.** He succeeds **Mr H. L. Evans.**

Mr E. G. Bell has joined Servomex Controls as sales manager (instruments).

Mr N. C. Lake has been appointed deputy managing director of Head Wrightson & Co Ltd, he will be responsible for the coordination of group sales to the iron and steel industry. The board of The Head Wrightson Export Co Ltd has been joined by **Mr Douglas Dodds-Parker,** MP.

Mr A. H. Hird has been appointed to the board of directors of Vickers Ltd. Mr Hird is already on the board of several Vickers subsidiaries.

Mr J. E. C. Bailey, CBE, chairman and managing director of Baird & Tatlock (London) Ltd and Hopkin and Williams Ltd is on a tour of company interests in South Africa and other Commonwealth countries.

Mr S. A. Dohm, founder chairman of the Dohm Group of companies is at present on a business visit to Africa.

Short & Mason Ltd, scientific instrument manufacturers, have appointed **Mr W. J. Lloyd** to the post of general manager. Mr Lloyd was previously with the scientific instrument division of Sunvic Controls Ltd.

Mr H. Desmond Carter has been appointed chairman of Crossley Brothers Ltd. Mr Carter who is already managing director succeeds **Sir Kenneth I. Crossley,** Bt who died in November of last year. **Mr Anthony Neville** has joined The Head Wrightson Export Co Ltd as manager, Europe.

At Racal Engineering Ltd **Mr A. St. G. Prynne** has been appointed commercial manager and **Mr I. H. M. Campbell** chief of sales.

Mr J. Driscoll has been appointed Sales Manager of The English Electric Company's Diesel Engine Division at Brownsover Hall, Rugby.

Mr Peter Elliott, general manager of Myton Ltd, building and civil engineering contractors, of Hull and London, has been appointed a director.

Mr E. Pearson has been appointed Assistant Sales Manager of Fielden Electronics Ltd.

Mr M. T. Clark becomes chief chemist at the Cricklewood laboratory of British Oxygen Gases Ltd on the retirement of **Mr C. Coulson-Smith.** Mr Clark has been at the Cricklewood Laboratory for the past 27 years.

At the beginning of January **Mr V. P. Scholes** took up an appointment as Midlands area representative for Kelvin & Hughes (Industrial) Ltd.

CATALOGUES & BULLETINS

Overhead linesmens' tools are fully catalogued in a new brochure from Bowthorpe Electric Co Ltd, Gatwick Rd, Crawley, Sussex.

Electrical Conductors: International Standard Sizes—is title of 84-page book compiled by British Insulated Callenders Cables Ltd, 21 Bloomsbury St, London, WC1. It contains in tabular form a comprehensive collection of all available data, much of it hitherto unpublished. It costs 15s post free.

Lead in construction of nuclear equipment—is subject of article in Lead News, Oct 1957. From Lead Development Association, 18 Adam St, London, WC2.

Sealing devices and connexions for electric cables are catalogued in new publication by Hellermann Ltd, Crawley, Sussex. Pressure bungs and water sealing glands are included.

Non-destructive testing of engineering materials—2nd edition of a monograph from A. E. Cawkell, 6-8 Victory Arcade, Southall, Middx—includes details of Cawkells' new LDA (logarithmic decrement attachment) instrument.

New heating mantles—type MY—are detailed in pamphlet from Electrothermal Engineering Ltd, 270 Neville Rd, London, E7.

Maps published by many official foreign and colonial bodies are sold by Edward Stanford Ltd, 12-14 Long Acre, London, WC2 are detailed in catalogue.

Tanks, linings, fume hoods and ducting, scrubbers, fans and pipework in corrosion resistant plastic materials are described in new brochure from Acalor (1948) Ltd, Kelvin Way, Crawley, Sussex.

Two new pamphlets from Venner Electronics Ltd, Kingston-by-Pass, New Malden, Surrey—time measuring equipment (leaflet VE105) and plug in stages (leaflet VE 104). Both these equipments are transistorized.

Audco Valves: power operation and remote control— is the title of new brochure from Audley Engineering Co Ltd, Newport, Salop. These are operated by air cylinders but Audley also make electrically operated valves—ask for separate pamplet on these.

Facilities for sheet metalwork, steel fabrication, design and manufacture of special purpose machinery, general machinery forgings and precision flame cutting are described in a brochure from Stern & Ball Ltd, Stour St, Birmingham, 18.

Nuclear Metals from A to Z

Sixteen years' close collaboration in the development of atomic energy projects, unrivalled technical knowledge and over a century of practical experience—these ingredients combine to give I.C.I. Metals Division a unique position in nuclear metallurgy.

In 1942, Europe's first uranium was extruded in an I.C.I. factory: an I.C.I. subsidiary, Marston Excelsior Limited, was one of the first commercial undertakings to be associated with the U.K.A.E.A. in the assembly of research reactor fuel elements containing enriched uranium.

Fuel elements for the research reactors Dido, Lido and Dimple; ancillary coolers, brazed assemblies, condenser tubes and plates for Calder Hall: 'Integron' finned tubing in steel for heat exchangers, in magnesium alloy for fuel cans: wrought and fabricated products in aluminium, steel, zirconium.

These are only a few of I.C.I.'s contributions to Britain's nuclear effort.

First in Nuclear Metals

IMPERIAL CHEMICAL INDUSTRIES LTD., LONDON, S.W.1.

ICI METALS DIVISION

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RESEARCH REPORTS

The following reports have been made available to the public by the United Kingdom Atomic Energy Authority. They may be borrowed or photocopies obtained from the Science Library, London, Department of Industrial and Forensic Science, Belfast, the Mitchell Library, Glasgow, and the Central Libraries at Acton, Birmingham, Bristol, Kingston-upon-Hull, Leeds, Liverpool, Manchester, Newcastle-upon-Tyne and Sheffield. They are also deposited in the Copyright Libraries (i.e. British Museum; University Library, Cambridge; Radcliffe Science Library, Oxford; National Library of Scotland, Edinburgh; National Library of Wales, Aberystwyth) and in the Patent Office Library. Reports marked may be purchased from Her Majesty's Stationery Office.*

Reports are also available in the United States, from the USAEC depository libraries, a list of which will be found in NUCLEAR SCIENCE ABSTRACTS. Reports for sale may be purchased in the United States from: Sales Section, British Information Services, 30 Rockefeller Plaza, New York 20, N.Y.

AERE Harwell

The atmospheric diffusion of gases discharged from the chimney of the Harwell pile (BEPO). *N. G. Stewart, H. J. Gale, R. N. Crooks.* (Oct 4, 1954) AERE HP/R 1452 9s*

Square wave polarography. Part 5. Organic adsorption-desorption waves. *G. C. Barker, A. W. Gardner.* (Nov 1955. 26 p) AERE C/R 1606 4s*

The analysis of zirconium/cerium binary alloys. *G. W. C. Milner, G. W. Sneddon.* (July 11, 1955. 11 p) AERE C/R 1554 2s 6d*

Hydraulically packed, inverted sphere beds. *D. A. Garton, F. Sterry.* (Oct 1956. 25 p) AERE ED/R 1882 4s*

The determination of long-lived fallout in rainwater. *R. G. Osmond, A. G. Pratchett, J. B. Warricker.* (Aug 1957. 21 p) AERE C/R 2165 3s 6d*

Apparatus for the preparation, analysis and investigation of plutonium solutions. *D. E Glanville, D. W. Grant, G. L. Strachan.* (Feb 28, 1957. 17 p) AERE C/R 2188 6s*

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The exchange of deuterium between hydrogen chloride and water. *O. Pugh, V. Y. Labaton.* (Aug 1957. 9 p) IGR TN/CA 652

The commissioning and operation experience of the Calder Hall reactors. *T. N. Marsham.* (Oct 1957. 16 p) IGT R-20

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ICE Institution of Civil Engineers. IMechE Institution of Mechanical Engineers. IEE Institution of Electrical Engineers. IChemE Institution of Chemical Engineers. IP Institute of Physics. PS Physical Society. SCI Society of Chemical Industry. IM Institute of Metals. IMet Institution of Metallurgists. IMM Institution of Mining and Metallurgy. IPE Incorporated Plant Engineers. SIT Society of Instrument Technology. BritIRE British Institution of Radio Engineers. WES Womens Engineering Society.

TUESDAY 4
LONDON IPE Some responsibilities of the civil engineering contractor's plant engineer *J. H. Brass, R. H. McGibbon* 7.00 at Royal Society of Arts, John Adam St, WC2

EDINBURGH IPE Testing of engineering materials, destructive and non-destructive, by mechanical, chemical X-ray and ultrasonic means *J. A. Menzies* 7.00 at 25 Charlotte Sq

LONDON IChemE 3 papers on fluidization by *J. F. Richardson, G. Bakhtiar, A. E. Mitson, A. D. Maude, R. L. Whitmore* 5.30 The Geological Society, Burlington House

THURSDAY 6
GLASGOW IPE Some factors concerning works capital expenditure *F. Franklin* 7.15 Scottish Building Centre, 425 Sauchiehall St

LONDON IMechE Lubrication group discussion on dry lubrication 6.00 at the Institution

WEDNESDAY 12
WOLVERHAMPTON BritIRE Industrial applications of radioisotopes *R. F. Armitage* 7.15 Wolverhampton and Staffordshire Technical College, Wulfruna St

THURSDAY 13
LIVERPOOL IPE Non-ferrous welding *E. A. Fareman* 7.15 at Exchange Hotel.

FRIDAY 14
NEWCASTLE IMechE Nuclear Power Stations *A. St John MacKellar* 6.30 at Grey Hall, King's College

TUESDAY 18
MANCHESTER IChemE Symposium on tools of chemical production management 3.00 at Reynolds Hall, College of Science and Technology

WEDNESDAY 19
ROCHESTER IPE Applications of photography in science and engineering *J. F. Padday* 7.00 at King's Head Hotel

BIRKENHEAD BritIRE Closed-circuit television *J. G. M. Downes* 7.00 at Birkenhead Technical College

LONDON IMechE Steam group discussion on availability of power plant 6.00 at the Institution

THURSDAY 20
BLACKBURN IPE Nuclear reactors for power production *J. A. Dixon* 7.30 Golden Lion Hotel

MANCHESTER IMechE Radioisotopes in engineering *J. L. Putman* 6.45 at Engineers Club, Albert Square

FRIDAY 21
EDINBURGH BritIRE Servomechanisms *R. Swainston* 7.00 at the Dept of Natural Philosophy, the University

TUESDAY 25
CARDIFF IPE Instrumentation *J. M. Keating* 7.00 at South Wales Engineers Institute, Park Place

LONDON ICE Prestressed concrete cylindrical tanks *L. R. Creasy* 5.30 at the Institution

BIRKENHEAD IChemE Ion exchange as a unit operation *R. Kressman* 7.00 at Birkenhead Technical College

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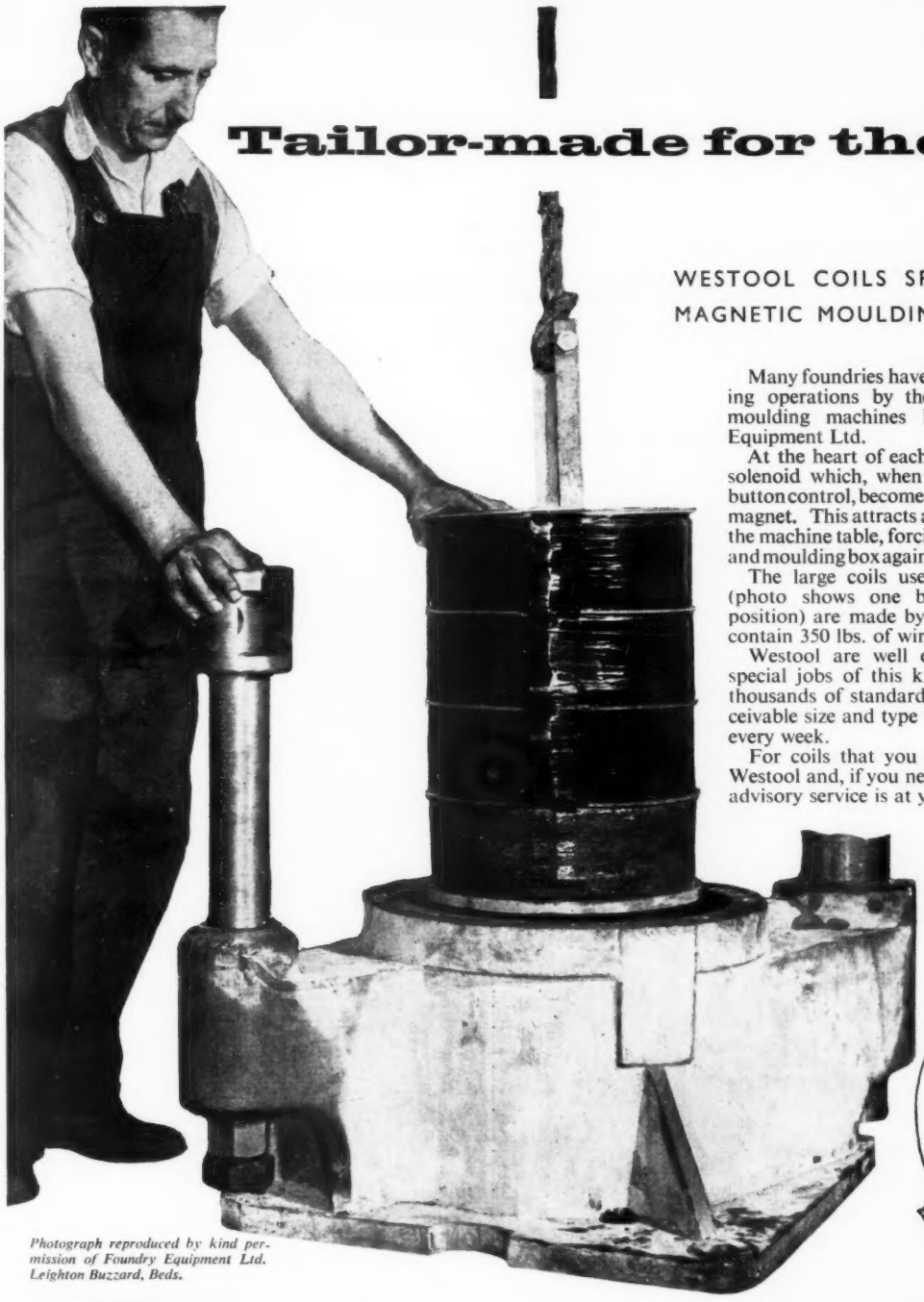

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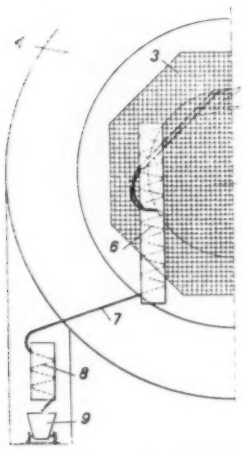
PATENTS

Letting them down gently

In our description of the G2 and G3 reactors at Marcoule (*Sept 1957*) the method of discharging hot fuel elements was indicated briefly. Details of the system are probably as given in this patent. In the big new French gas-cooled piles, the fuel channels are horizontal and elements are discharged simply by pushing in a new one at the charge face. The problem now is to take care of the hot element and prevent it becoming broken. According to the invention, on leaving



787,971 MARCOULE HELTER-SKELTER

1 Core
2 Fuel channels
3 Reflector
4 Concrete pressure shell
5 Straight chutes connecting diagonal line of channels
6 Spiral chute
7 Straight chute leading outside pressure shell
8 Second spiral chute
9 Truck

the channel it is turned through a right angle in a sloping chute (5) and then conveyed to a cylindrical duct (6) fitted with an internal helical chute. In this a relatively low terminal velocity is achieved and the slug then emerges along channel (7) to another spiral chute (8) in which it is further slowed down. It is finally dumped into a sand-filled truck (9) running in a tunnel through the biological shield.

787,971 Improvements in devices for discharging rods of fissionable material from nuclear reactors Commissariat à l'Energie Atomique, Paris (Inventor: Sebastien Foglia) Appn: June 19, 1956 Pubd: Dec 18, 1957

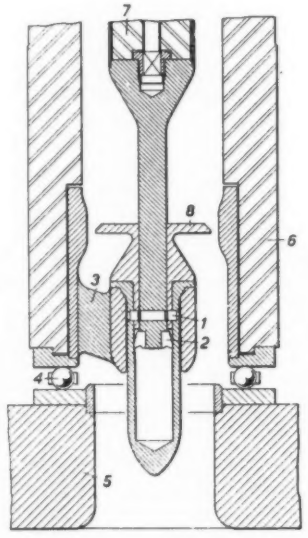
Individual support for elements

At one time it was proposed to use separate supports for the Calder Hall fuel elements and this patent covers the idea. The idea was to attach a spider with three hinged legs to the top of each fuel cartridge. The legs were spring-loaded outwards and located in circumferential grooves cut in the graphite blocks. Since neutron economy is so important, these spiders would have to be in beryllium or zirconium. A beryllium one was illustrated at the BNEC's Calder Hall symposium.

784,890 Improvements in or relating to fuel elements for nuclear reactors. United Kingdom Atomic Energy Authority (inventor, K. H. Dent) Appn: Aug 25, 1955. Pubd: Oct 16, 1957

Shear pin and broach

Another Calder patent, this deals with the method of supporting the stack of fuel elements to allow for differential expansion between the base support members and the moderator. It also provides a shear pin and broach device at



783,094 CALDER FUEL SUPPORT

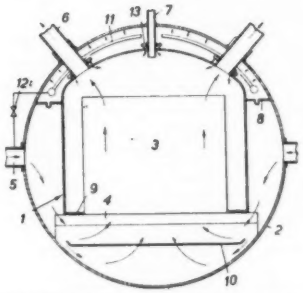
1 Shear pin
2 Broach
3 Spider support
4 Ball bearing
5 Core plate
6 Graphite structure
7 Support strut
8 Channel gag

the bottom of the column so that the accidental dropping of a fuel element on to the column does not cause permanent damage. The assembly also includes an annular plate, known as the gag, by means of which the amount of coolant entering the particular channel can be regulated. This is described in more detail in the article on p. 58, this issue.

783,094 Improvements in or relating to support devices for use in nuclear reactors. United Kingdom Atomic Energy Authority (inventors: F. C. Greenhalgh and E. Long) Appn: July 28, 1954. Pubd: Sept 18, 1957

Double-skin pressure vessel

One design difficulty of the British type of gas-cooled reactor is in the design of the pressure vessel to withstand the pressure and heat for many years of continuous operation. Taken out by GEC's nuclear chief, R. N. Millar, and a colleague this patent shows how it is being tackled at the firm's Hunterston station. Briefly, the idea is to use two shells—one to withstand heat but little pressure, the other for pressure only. Five different forms of construction are described in the specification, the one shown



785,945 THICK OUTSIDE, THIN INSIDE

1 Inner shell
2 Outer pressure vessel
3 Core
4 Support grid
5 Main gas inlet
6 Main gas outlet
7 Charge tube (one of many)
8 Outer gas seal
9 Inner gas seal
10 Deflector
11 Cool gas distribution
12 Gas bypass
13 Mechanical seals

here corresponding most closely to Hunterston. Note how some fresh coolant gas is bypassed and distributed round the top part of the outer sphere and allowed to leak into the inner shell. By this type of construction, the outer shell can be in ordinary boiler plate while the inner shell can be in relatively thin heat-resisting steel.

785,945 Improvements in or relating to pressure vessels The General Electric Co Ltd (Inventors: R. N. Millar and K. J. Mitchell) Appn: May 31, 1955 Pubd: Nov 6, 1957

Neutron source for well-logging

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784,641 Neutron well logging apparatus. Schlumberger Well Surveying Corporation Appn: Dec 20, 1954 Pubd: Oct 16, 1957

Photograph of Remote Handling equipment by arrangement with Messrs. Savage & Parsons Ltd., Watford

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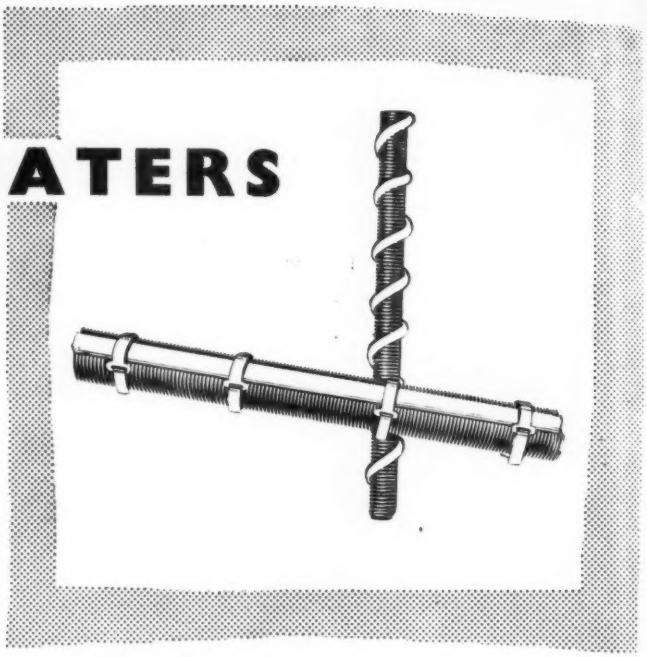

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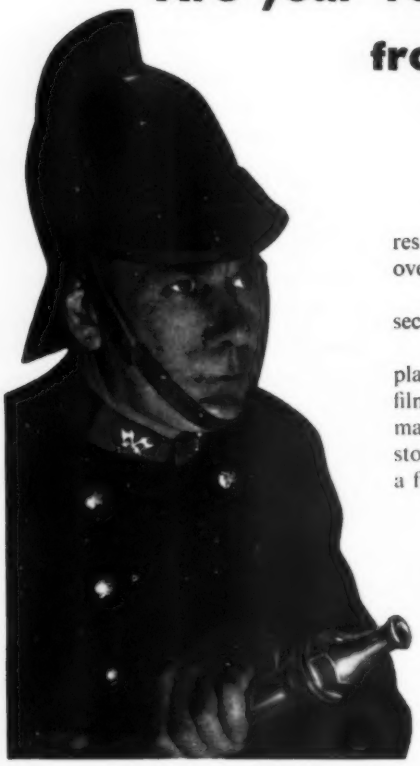

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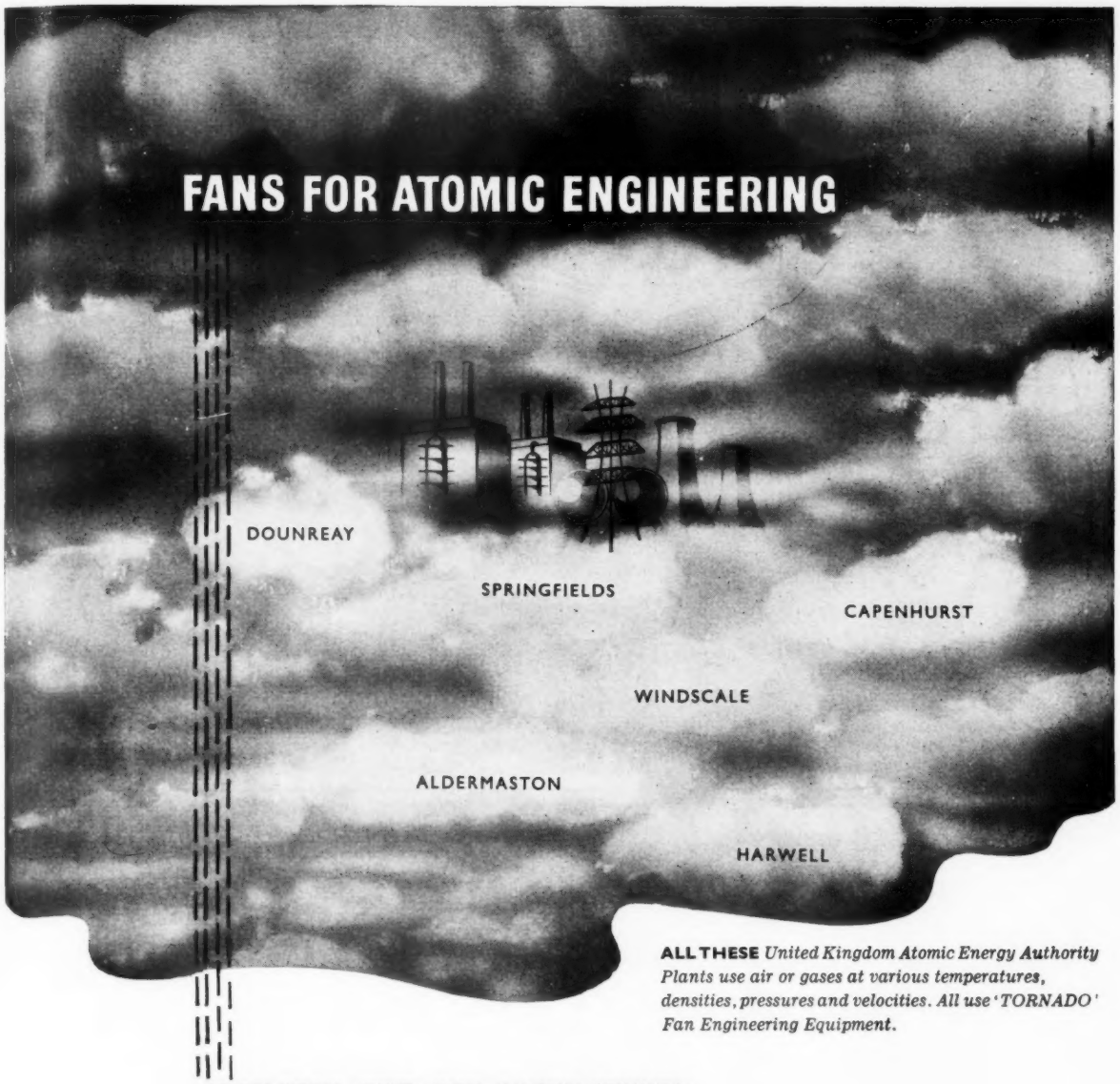

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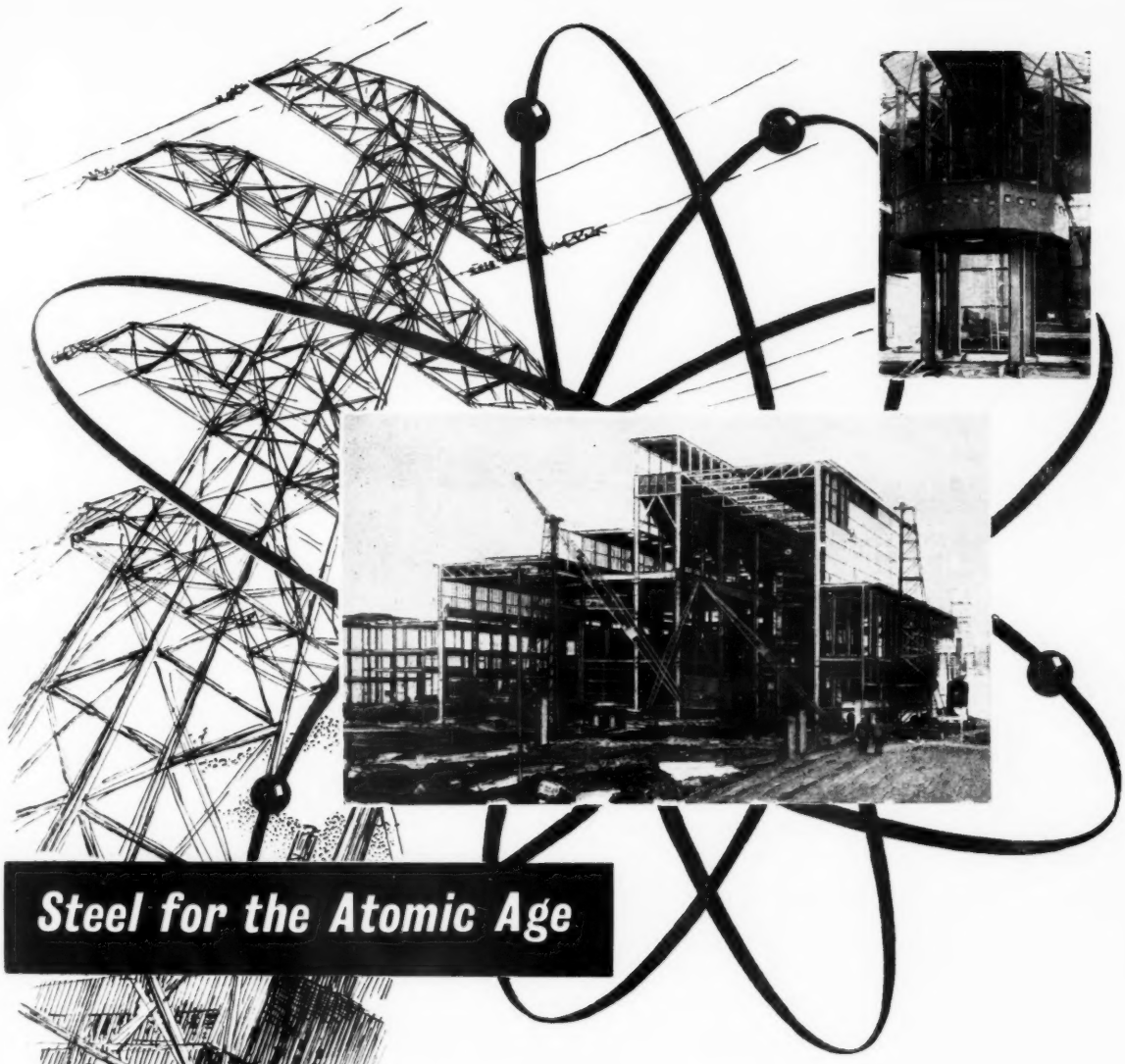

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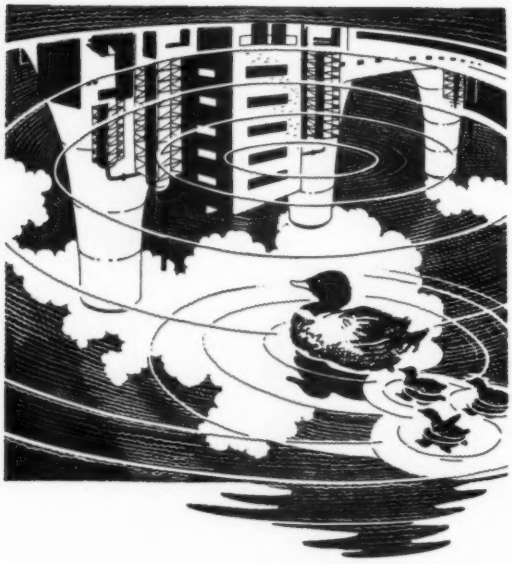

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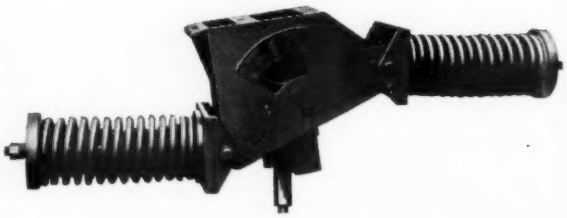

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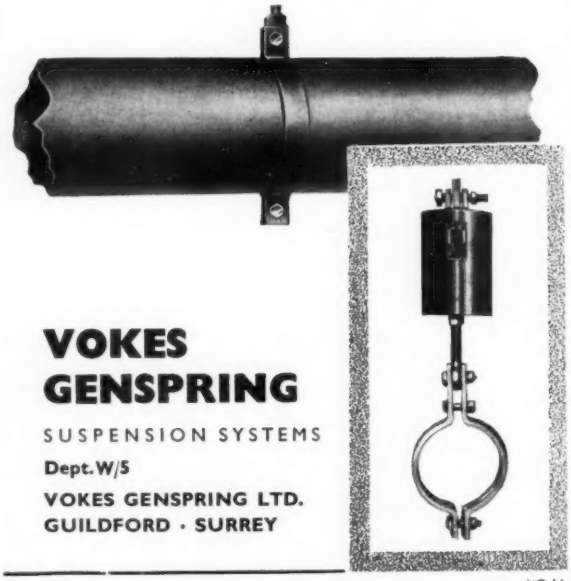

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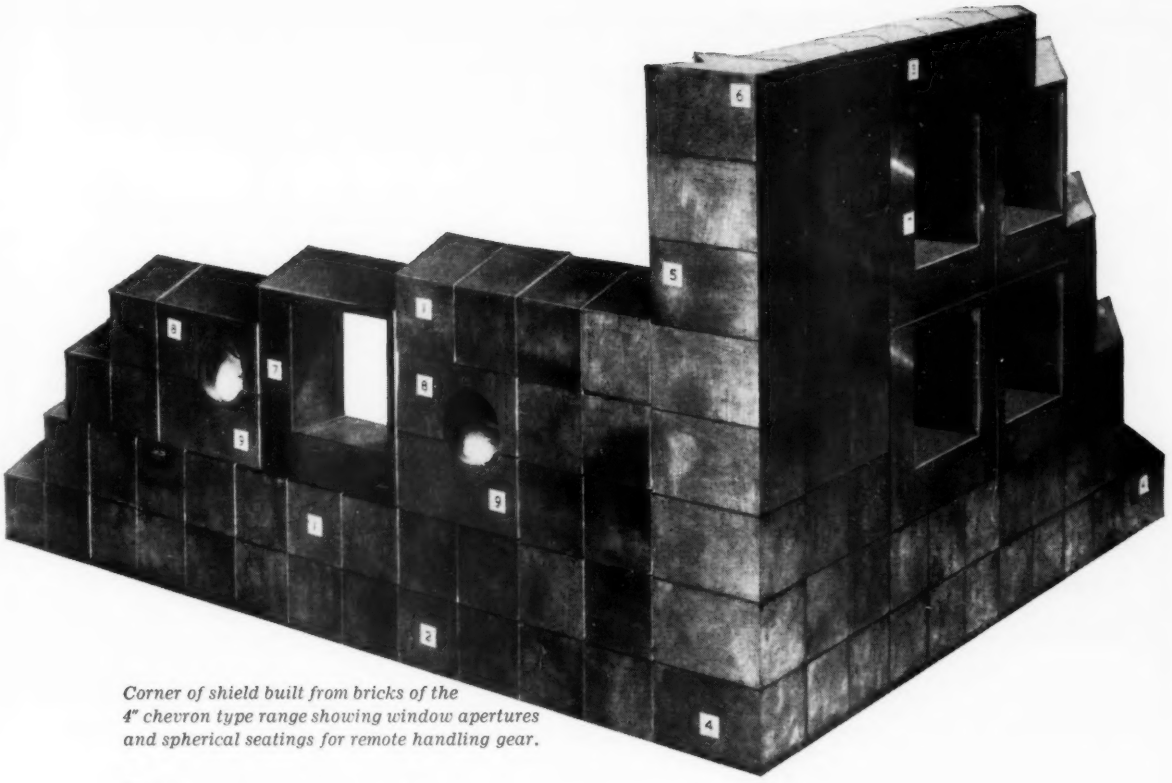

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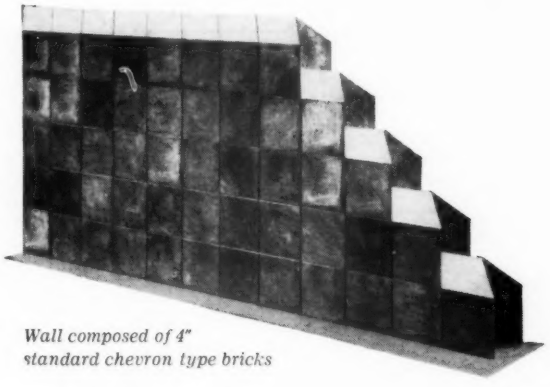

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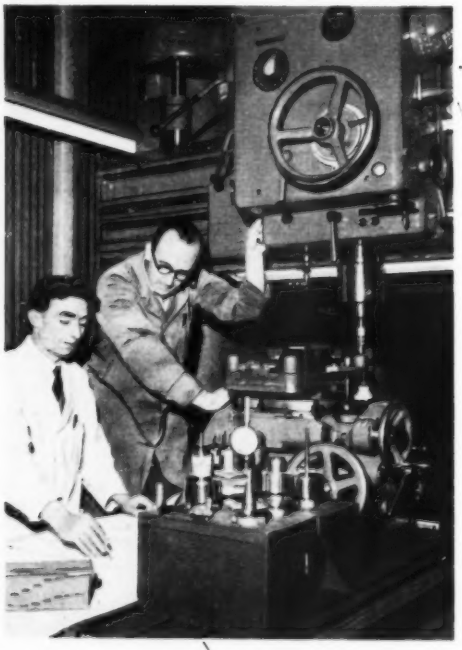

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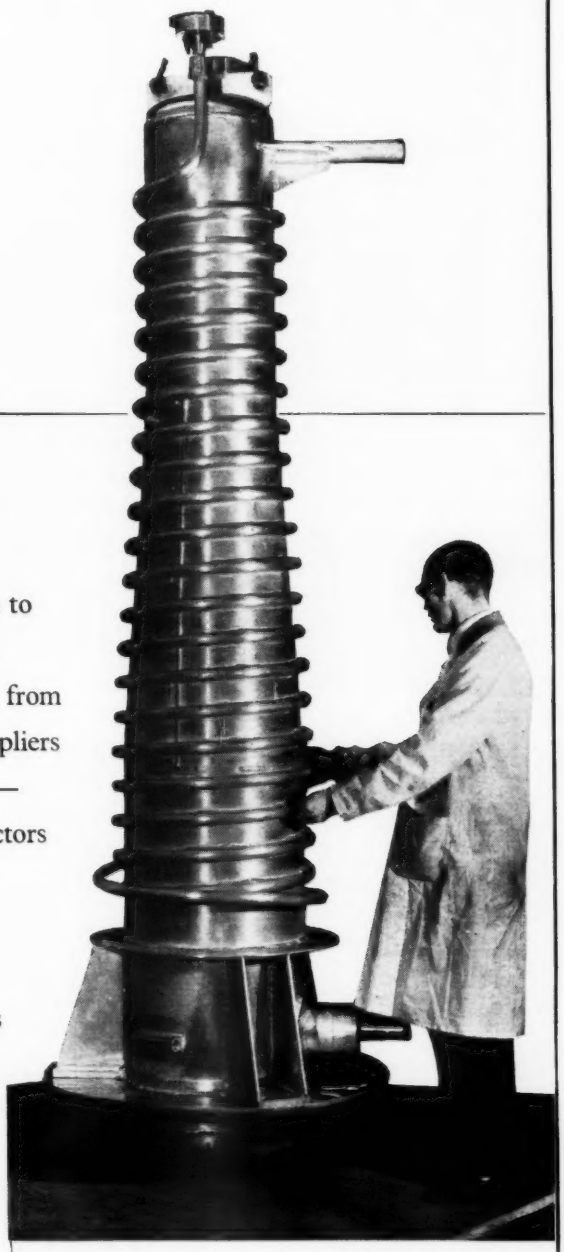

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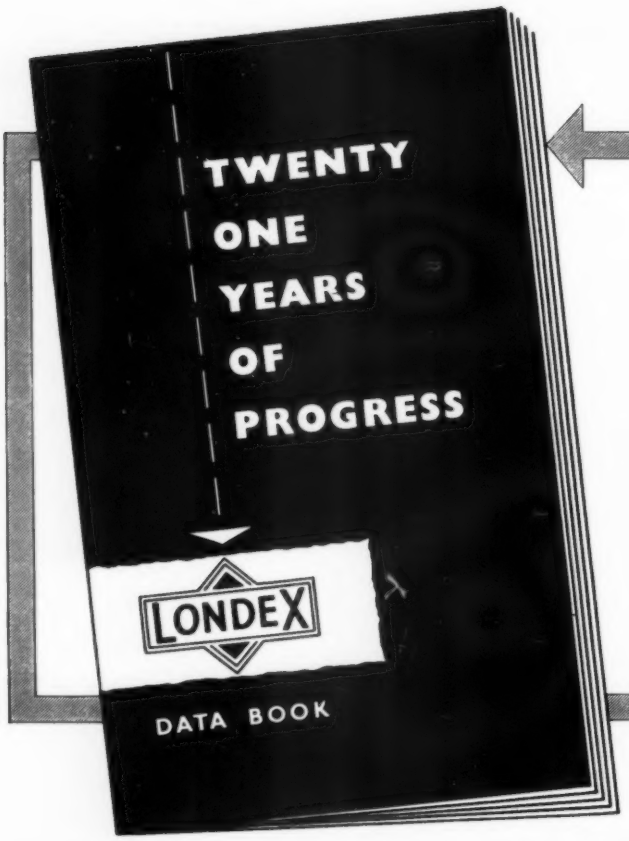

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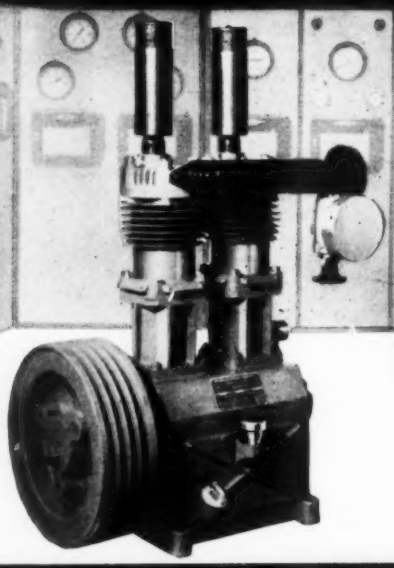

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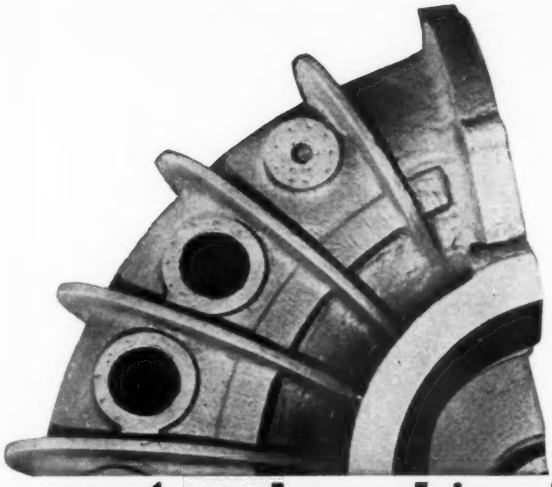
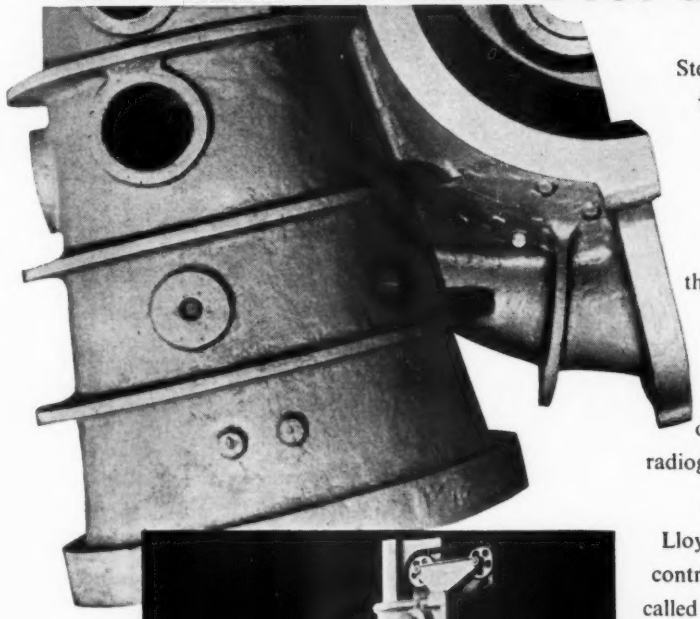


Half gas circulator casing cast in steel and machined for C. A. Parsons & Co. Ltd. for Nuclear Power Station, Calder Hall. Weight as cast 35 tons. Sectional thickness max 7" min 1½". Reproduced by permission of C. A. Parsons & Co. Ltd.

cast and machined for an important part



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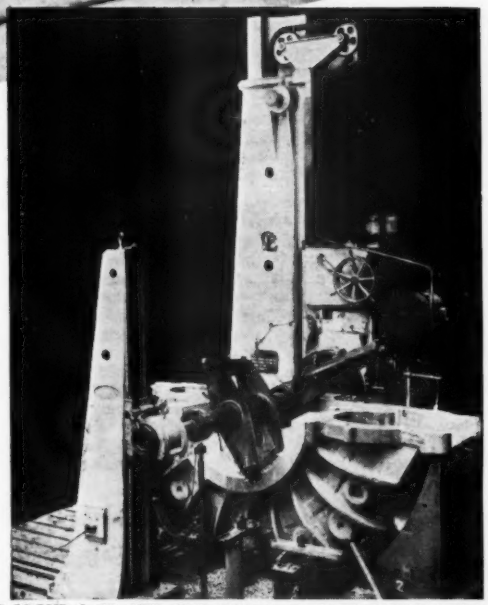

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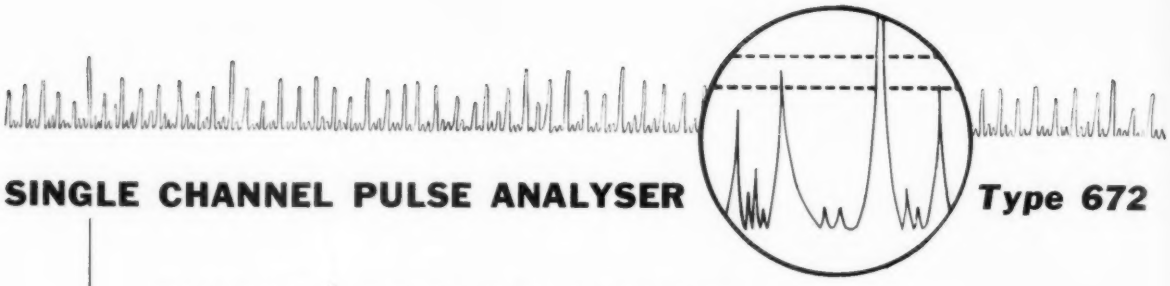

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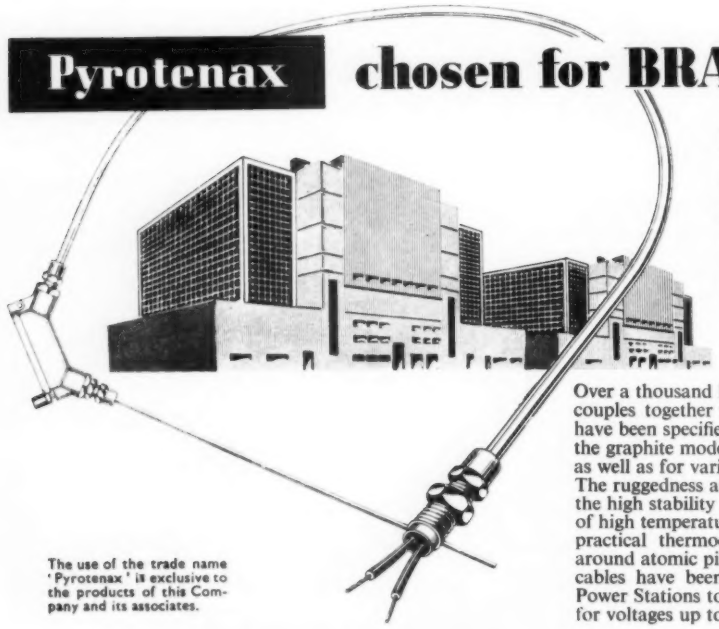
Pyrotenax chosen for BRADWELL



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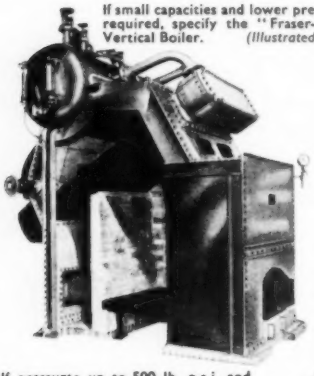

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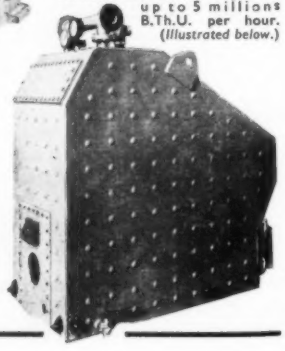

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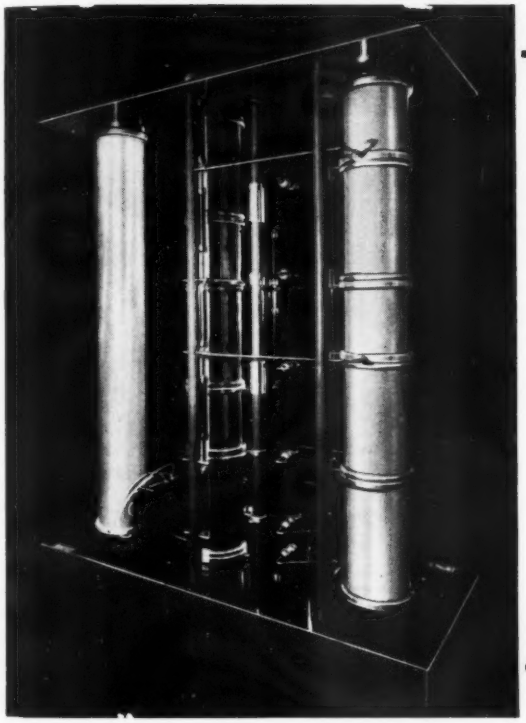

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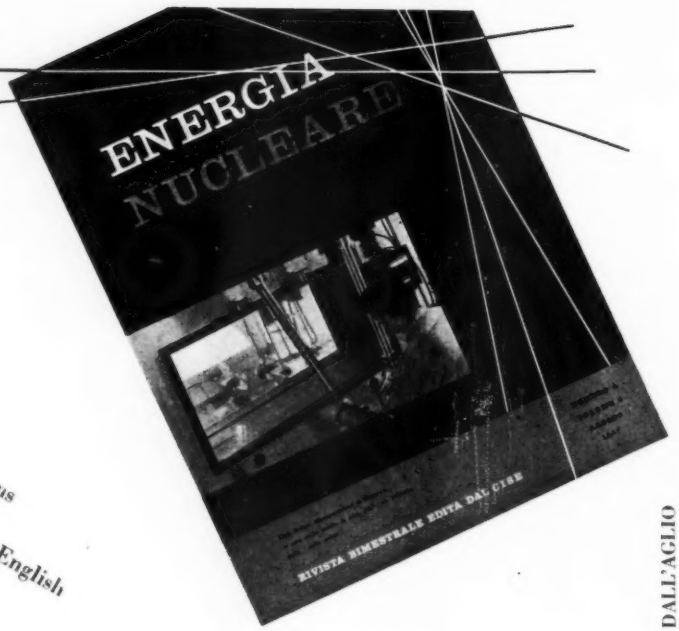

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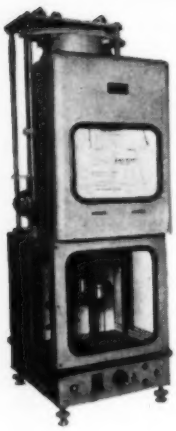

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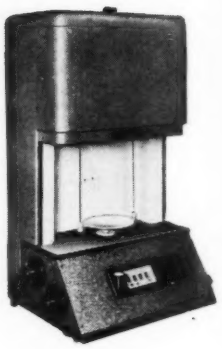

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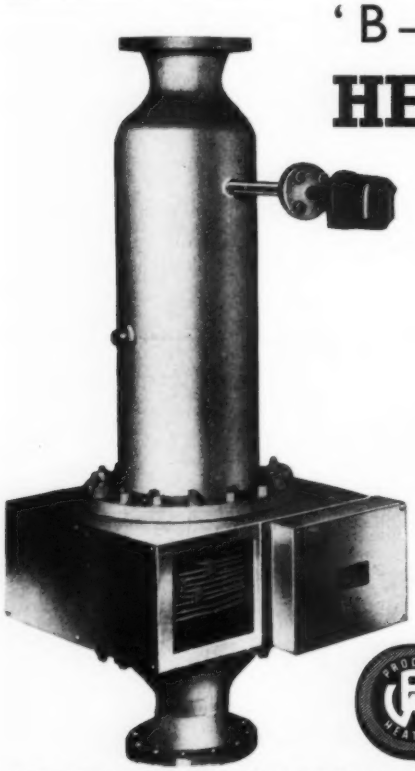

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ZETA

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MULTI-CHANNEL OSCILLOSCOPES

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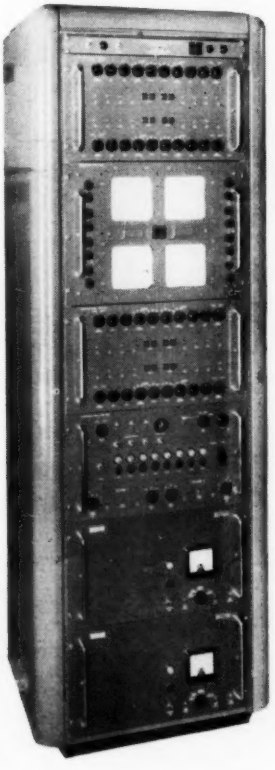

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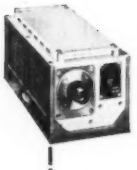

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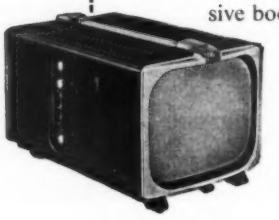

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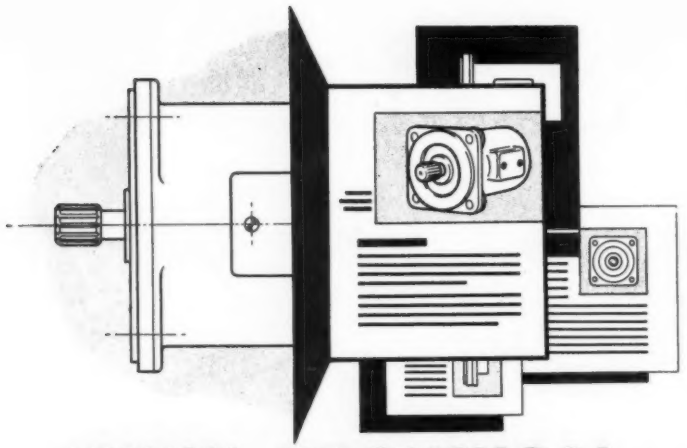

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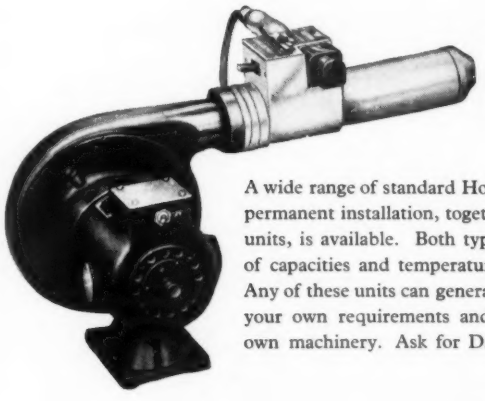

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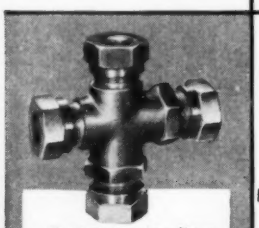

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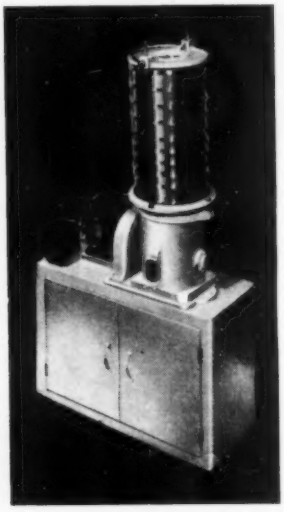

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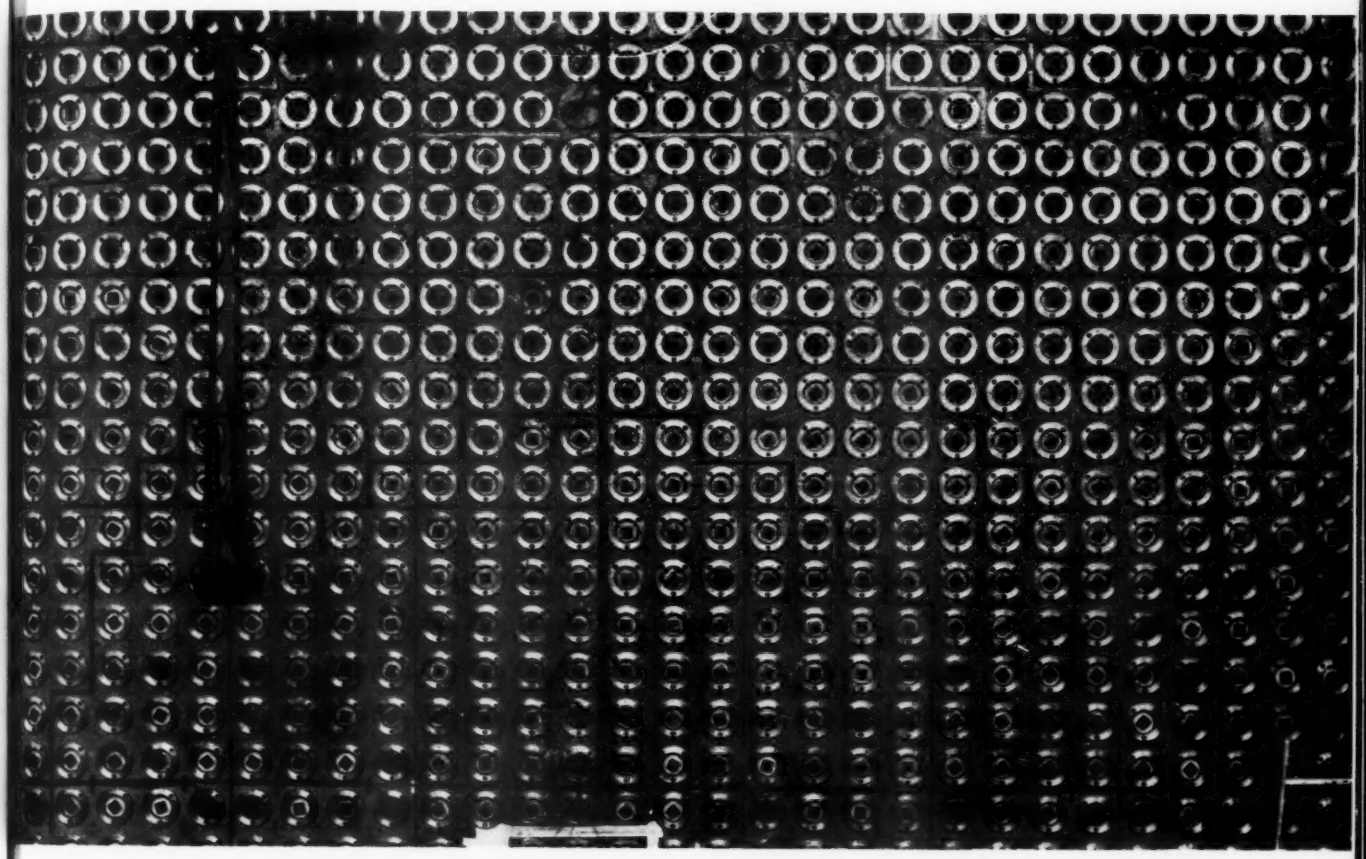

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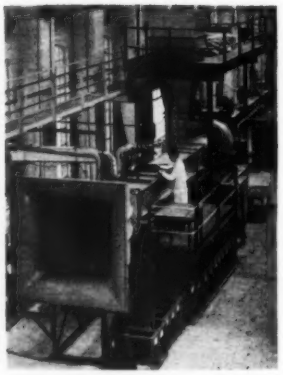

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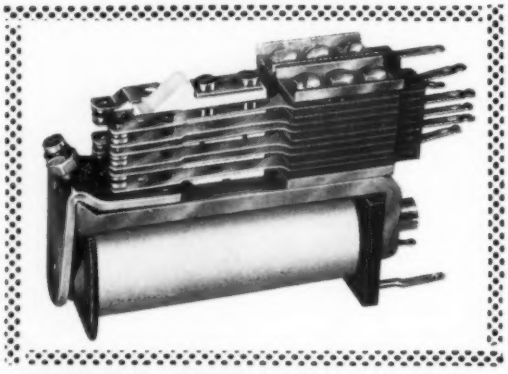

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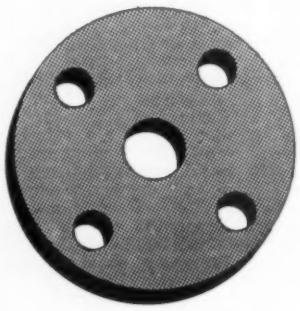

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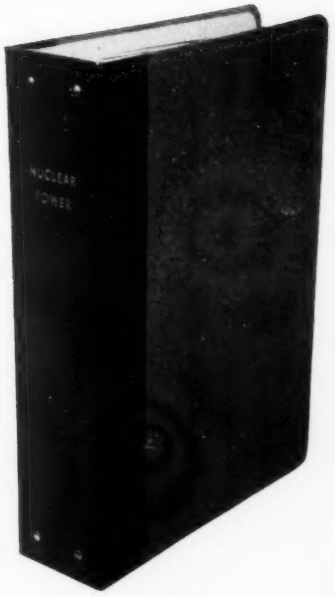

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Yarrow & Co Ltd A78
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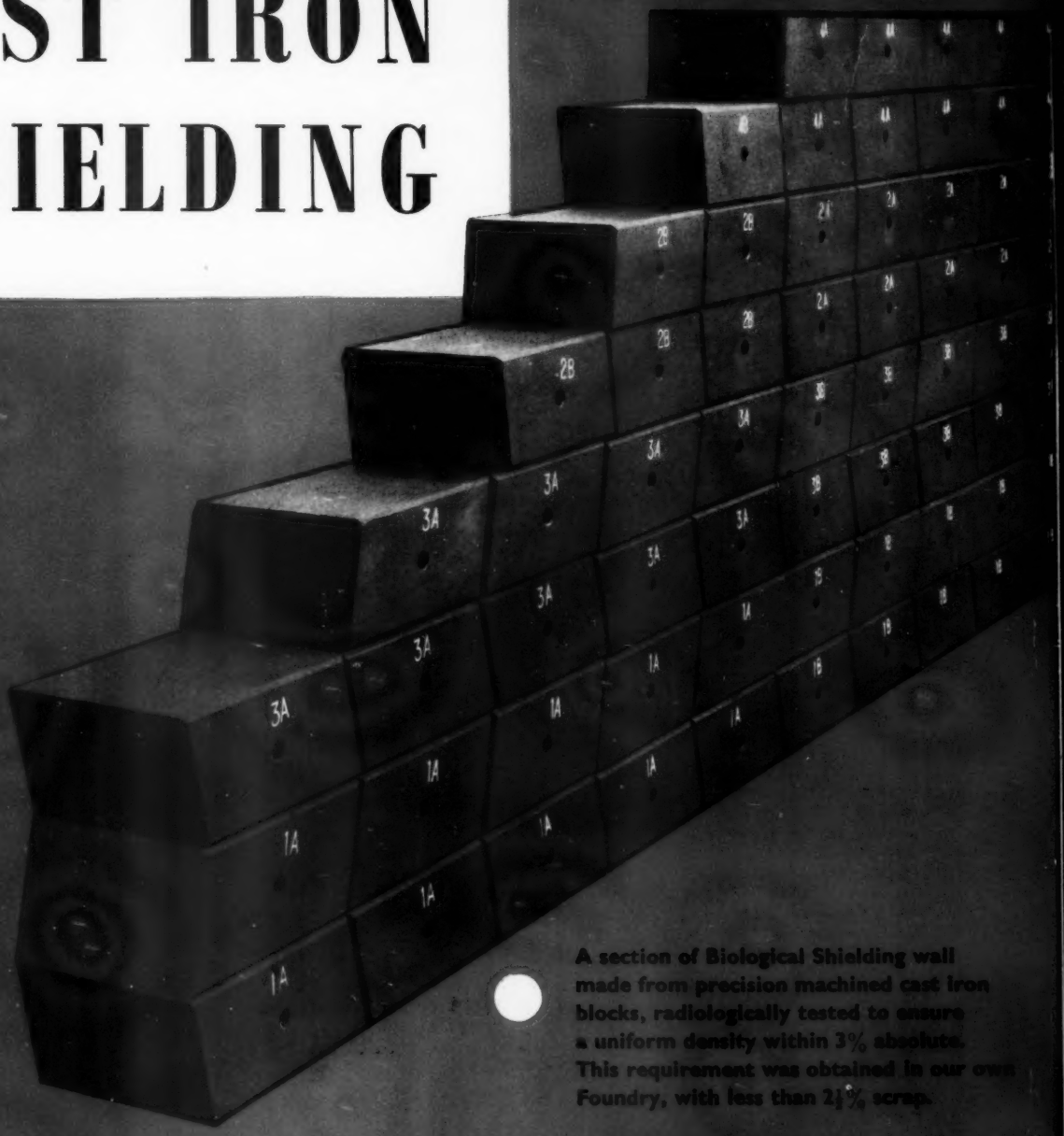
CAST IRON SHIELDING



A section of Biological Shielding wall made from precision machined cast iron blocks, radiologically tested to ensure a uniform density within 3% absolute. This requirement was obtained in our own Foundry, with less than 2½% scrap.

Typical sample of shielding delivered to Harwell and Dounreay on a sub-contract order from Messrs. Head Wrightson Processes Ltd.

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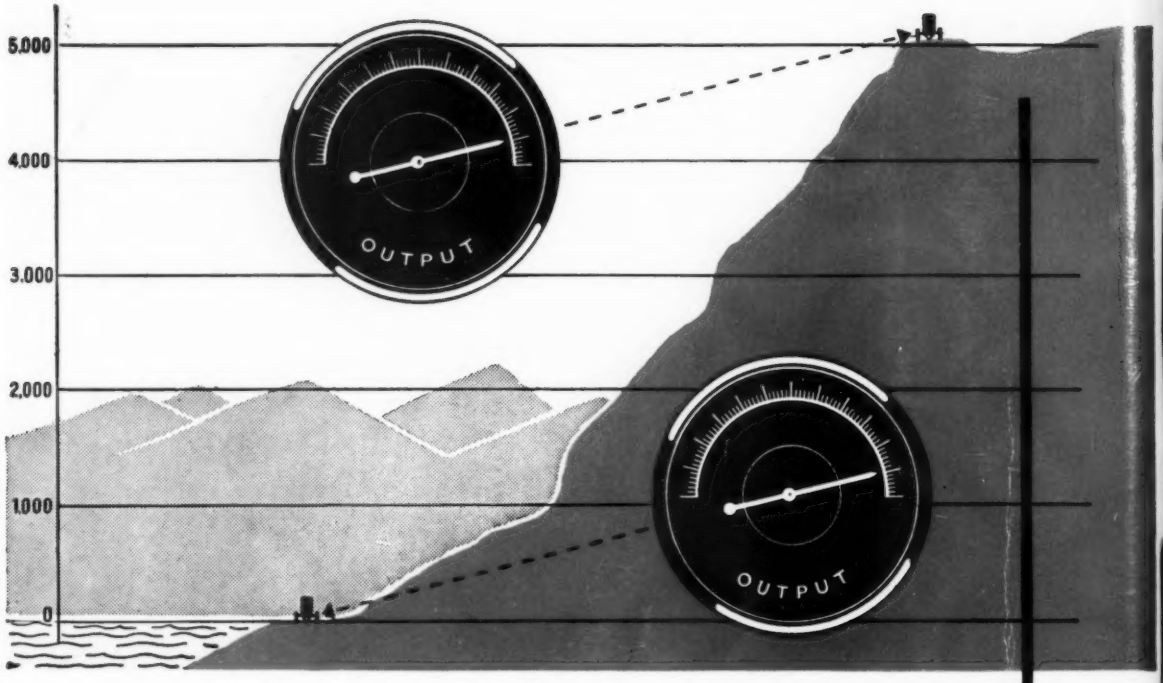

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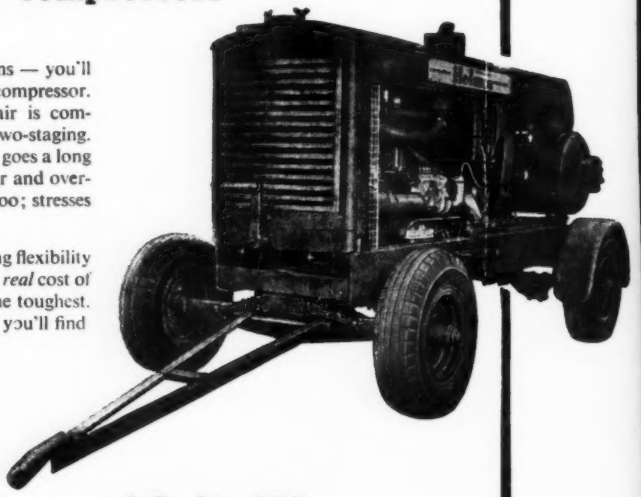

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